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**Sensory-Specific Satiety
and Repeated Exposure to Novel Snack Foods:
Short- and Long-term Changes
in Food Pleasantness Ratings**

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Thesis submitted to the University of Sussex in November 2012
for the degree of Doctor of Philosophy in Experimental Psychology

- = D E C L A R A T I O N = -

I hereby declare that this thesis has not been submitted, either in the same or different form, to this or any other University for a degree.

Sarah Louise Robins-Hobden

16th NOVEMBER 2012

To Daniel
My husband, my hero.
Mischief Managed.

- = A C K N O W L E D G E M E N T S = -

With greatest thanks to my husband Daniel. We both know I could not have done this without you. Thank you for keeping me sane - a feat that easily exceeds that of researching a doctorate. Love you to bursting.

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* www.literatureandlatte.com

UNIVERSITY OF SUSSEX

Sarah Louise Robins-Hobden

Doctor of Philosophy in Experimental Psychology

**Sensory-Specific Satiety and Repeated Exposure to Novel Snack Foods:
Short- and Long-term Changes in Food Pleasantness.**

- = S U M M A R Y = -

Sensory-specific satiety (SSS) is a significantly greater pleasantness decline for a consumed (Eaten) food, than foods that are tasted but not consumed (Uneaten). SSS occurs during consumption, reaches optimal magnitude immediately afterwards, and returns to baseline within two to three hours. The phenomenon is dependent on the sensory properties, rather than the energy or macronutrient content of the food. To the extent that an Uneaten food shares similar sensory properties with the Eaten food, the Uneaten food may be subject to pleasantness decline: a transfer effect.

Repeated exposure to a food stimulus may alter liking in the long-term, through mere exposure, monotony, and dietary learning paradigms resulting in an association between the novel target food and either a known food stimulus, or a consequence of consumption. Novel foods are more susceptible to these effects than familiar foods, for which learned associations may have already formed. Repeated consumption alone does not modulate SSS, but to date such studies have not tested novel foods.

Through six experiments this research explores the influences of long-term pleasantness changes of novel foods and the number and type of Uneaten foods present during SSS testing, on the magnitude of SSS for snack foods.

While no evidence of mere exposure or dietary learning was found, and in some instances experiments failed to induce SSS, these negative results are likely due to methodological, and sometimes procedural issues in the design and conduct of experimental testing. Findings revealed SSS to be vulnerable to a number of procedural and methodological factors, such as: portion size; baseline novelty and pleasantness ratings; hunger; perceived ambiguity of measurement scales; and expectations raised by the type and number of Uneaten foods present during testing.

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CHAPTER 1: General Introduction

1.1. Overview of the Hedonics of Food

Consumption of nutrients is essential to human life and therefore we must eat. As a species humans have ritualised feeding into meals and snacks, often turning group eating into a social event such as a business lunch, family meal or dinner party. Many of our feeding and drinking choices such as what and how much to eat, and when to start and stop eating, are mediated not only by physiology but also by the pleasure we receive from consuming particular foods. These subjective hedonic evaluations are subject to individual differences and therefore not an inherent characteristic of the food or drink in itself. Food preferences may be innate (such as a liking for sweetness) or learned (such as a liking for energy-dense foods). The hedonic value of particular foods and drinks can increase or decrease, and the length of time in which these changes occur and persist varies greatly. Such changes are in our attitude to a particular food, and consequently affect the frequency and quantity of the food that is consumed.

On a very short time-scale a decline in liking for a food being consumed may occur within, or shortly after a meal. In one experiment when individuals were given access to *ad libitum* food then asked to give a reason for terminating the meal, the most common response was "I got tired of eating the food" (Hetherington, 1996), which may be interpreted as hedonic fatigue, and was closely related to the decline in liking for the food consumed. Such a change may be attributed either to negative alliesthesia, whereby physiological responses to nutrients in the digestive tract reduce hedonic responses to the food being eaten (Cabanac, 1971), or to sensory specific-satiety (SSS), whereby the reduction in pleasantness is associated with the sensory characteristics of the food being eaten, rather than the nutritional aspects. Both negative alliesthesia and SSS are short-term modulators of food hedonics, typically lasting no longer than an hour or two. However, there is overwhelming evidence to suggest that SSS is the best explanation for post-consumption pleasantness decline, at least in a snack context (Atton, 2006), as it occurs too rapidly to be attributed to nutrient absorption (see Section 1.2.2.3: Energy and Macronutrient Content).

On a longer time-scale, novel foods may become increasingly liked over time, an effect termed "mere exposure" by Zajonc (1968). Conversely, monotony may induce a decreased liking for a novel food over a similar period. Changes in liking as a result of

mere exposure or monotony may last for days, weeks or even longer, though the magnitude of these changes appears to decline over time (e.g. B. J. Rolls, Van Duijvenvoorde, & Rolls, 1984). The effects of mere exposure and monotony do not rely upon any learned association, though may provide the basis for subsequent learning, as exposure is necessary for learning to occur (see Section 1.3.1: Mere Exposure and Monotony).

Dietary learning (see Section 1.3.3: Dietary Learning) can be responsible for chronic hedonic changes that persist for much longer time-scales, perhaps even permanently. Flavour-based learning occurs when an association is formed between the stimulus food, and either a similar flavour, or a consequence of consuming the food (see Section 1.3.3.1: Flavour-Based Learning). For example, changes in liking may alternatively be associated with a flavour that is already liked or disliked. The extent of the transference of hedonic valence from one (familiar) food or flavour stimulus, to another (novel) food or flavour stimulus, will depend much on the extent to which they share the common sensory aspect to which an attitude has been formed. This kind of dietary learning is referred to as flavour-flavour learning (FFL) and falls within the realms of associative learning. When an association is formed between the flavour of a particular food and a post-ingestive consequence of that food, it is termed flavour-consequence learning (FCL). When the consequence is negative (e.g. food poisoning), the resulting aversion is usually much stronger and longer-lived than a learned preference formed by an association with a positive consequence (such as physiological arousal induced by caffeine - see Section 1.3.3.1: Flavour-Based Learning).

Finally, "learned satiety" refers to an acquired control of intake as a result of associating a flavour with perceived post-consumption satiety. Initially evidence for learned satiety arose from experiments on rats (Booth, 1972), and the same laboratory subsequently provided evidence of the same phenomenon in humans (Booth, Lee, & McAleavey, 1976), although this effect has been exceedingly difficult to replicate (see Section 1.3.3.2: Learned Satiety).

This focus of this thesis is sensory-specific satiety as a short-term hedonic change in the context of snack foods (as opposed to meals) and how it may be modulated by long-term hedonic changes, specifically those induced by mere exposure, monotony, flavour-based learning, FCL, and learned satiety. Hence, the remainder of this chapter provides a

comprehensive exploration of each of these individual concepts, how they may interrelate, and their possible effects on sensory-specific satiety.

1.2. Sensory-Specific Satiety

1.2.1. Evidence for Sensory-Specific Satiety

Early work on SSS grew from the results of experiments conducted on the feeding behaviour of rats. Historical evidence for SSS in non-humans is derived from studies in which rats were satiated on particular food item, yet would return to feeding if alternate food items became available. This has been shown with the consumed food being, for example, a synthetic solid food (Le Magnen, 1999); an energy-free saccharin solution (Mook, Kushner, & Kushner, 1981); and a high-energy glucose solution (Mook, Brane, Kushner, & Whitt, 1983). In each of these studies, rats showed willingness to consume alternate foods when satiated on the Eaten food, with a consequence of greater consumption being observed when the diet was varied. The animal evidence for SSS is discussed in greater detail in Section 1.2.1.2: Sensory-Specific Satiety in Non-Human Animals. The rat behaviour draws parallels with human ingestive behaviour in food choice situations, which subsequently came to be defined as sensory-specific satiety, and led to examination of the phenomenon in humans.

The first experimental evidence of SSS in humans was provided by Rolls *et al.* (1981) and clearly outlines the phenomenon whereby a food that is consumed declines in pleasantness during the course of consumption. In this original experiment, participants tasted eight food samples and rated them for pleasantness, then ate one of the foods to satiety (the 'Eaten' food). Post-consumption pleasantness ratings were taken again for all eight foods at 2 minutes and 20 minutes later. With the exception of roast beef, all foods (chicken, walnuts, chocolate, cookies, raisins, bread and potatoes) significantly declined in pleasantness from baseline ratings, at both post-consumption time points. In addition, the decline in pleasantness for the Eaten food in each instance (except for beef), was significantly greater than that of the foods tasted but not consumed (the Uneaten foods). Several laboratories have since been able to replicate SSS using similar experimental methods with variations (for example: fixed portion of the Eaten food vs. eating to satiety; rating the pleasantness of the taste and smell of the foods, along with other ratings for texture, appearance etc.) (e.g. Bell, Roe, & Rolls, 2003; Hetherington, 1996; Hetherington, Rolls, & Burley, 1989; Raynor, Niemeier, & Wing, 2006; B. J. Rolls, *et al.*, 1984; E. T. Rolls, Rolls, & Rowe, 1983; Snoek, Huntjens, Van Gemert, De Graaf, & Weenen, 2004; Vandewater & Vickers, 1996; Weenen, Stafleu, & de Graaf, 2005).

1.2.1.1. Sensory-Specific Satiety in Humans

SSS has been demonstrated for the pleasantness of various modalities of the food, such as the taste, smell, appearance and texture, for example Hetherington and Rolls (1989) provide evidence for a significant decline in rated pleasantness of the taste, smell, texture and appearance of the Eaten food, against Uneaten foods. Guinard and Brun (1998) found SSS for the taste (sweet and savoury) and texture (sandwiches vs. baguette and apples vs. apple sauce) of foods, independently of the flavours the foods impart. Visual appearance of food may be very important in SSS, (E. T. Rolls, et al., 1983), indeed satiety has been shown to be specific to differences in the colour of chocolate, with pleasantness declining for one colour of Smarties (Rowntree), but not others (B. J. Rolls, Rowe, & Rolls, 1982). The same experiments saw SSS specify to the particular shape of pasta, while other shapes did not significantly decline in pleasantness, providing good evidence for texture effects in SSS.

In SSS the Eaten food declines in pleasantness to a significantly greater degree than Uneaten food(s). However, there is an exception to this in the form of transfer effects. To the extent that an Uneaten food shares sensory similarities with the Eaten food, the Uneaten food may also decline in rated pleasantness: the Uneaten food becomes subject to the transfer effect. For example, one experiment indicated decline in hedonic ratings for (Uneaten) chicken, after having eaten sausages to satiety and an increase in liking for sweet Uneaten foods when the Eaten food was savoury (cheese on cracker) (B. J. Rolls, et al., 1981). Another (B. J. Rolls, et al., 1984) found that both cheese on cracker and sausages, when consumed, resulted in decreased pleasantness of other savoury foods, but not sweet foods. Raynor and Wing (2006) found that the consumption of cake reduced the pleasantness of other sweet (Uneaten) snacks, but not of salty snacks. The same effect has been shown for a flavour similarity, where pleasantness for (Uneaten) ground beef in a tomato sauce was greatly reduced as a result of consuming a portion of pasta in a different tomato sauce (Johnson & Vickers, 1993). In the same paper, Johnson and Vickers speculate that transfer effects between chicken and pork may be attributed to more than one modality - not only are both meats savoury and of similar texture, but they are similar in colour and appearance too.

The findings of another experiment (Guinard & Brun, 1998) confirmed transfer effects that were generalised simply to the taste of the food: sweet Eaten foods resulting in pleasantness decline for sweet Uneaten foods, but not for savoury, and vice versa.

Transfer effects have subsequently emerged in a number of more recent studies (e.g. Atton, 2006; Hetherington, Bell, & Rolls, 2000; B. J. Rolls, Hetherington, & Burley, 1988b; Weenen, et al., 2005).

Sensory-specific satiety occurs during eating, in a single exposure (Hetherington, Pirie, & Nabb, 2002). Evidence suggests that the decline in pleasantness is optimum immediately post-consumption (Hetherington, et al., 1989), is still significant up to an hour after eating (Atton, 2006), and may still present at 120 minutes post-consumption (B. J. Rolls, Hetherington, & Burley, 1988a; Weenen, et al., 2005). In these studies, comparisons were made between time-points on net Change In Pleasantness ratings calculated by deducting post-consumption rating from each time-point from the pre-consumption rating (see Section 2.1: Methodology and Measurement of SSS in the Literature).

Several aspects differentiate SSS from general satiety. The decline in pleasantness of the Eaten food is related to the sensory aspects of that food, and is not observed in sensorially different Uneaten foods, which we would expect if the experienced satiety was general and not specific (B. J. Rolls, et al., 1984). Very low-calorie foods can produce SSS, and this indicates that the sensory properties of foods are important for the changing hedonic response to foods as they are consumed, rather than energy intake (B. J. Rolls, Hetherington, et al., 1988a). SSS occurs immediately after eating, and therefore too early to be attributed to post-ingestive consequences related to the energy or macronutrients imparted by the Eaten food (Hetherington, 1996; Hetherington, et al., 1989).

In addition, a food does not have to be ingested at all, in order for SSS to occur. Indeed, in one sham-feeding experiment (Smeets & Westerterp-Plantenga, 2006), significant decline in pleasantness was recorded for foods chewed then expectorated (not swallowed). This makes sense, as sensory experiences are concentrated in the mouth and nasal cavity through a combination of taste, olfactory and haptic modalities (see Section 1.2.2.1: Taste Perception Deficits), and are therefore not available after swallowing. In this particular experiment, duration of the oral exposure did modify the extent to which SSS developed, with longer chewing times being closely related to greater hedonic declines. It is worth noting that although SSS developed as a result of chewing salad, the same effects were not replicated with soup. This indicates that duration of oral exposure may not be the only factor at work in instigating SSS, but also possibly the effort involved in masticating the food, and the extent to which the food provides a sensory experience while it is being chewed. For example, soup is a fairly homogenous food that does not

require chewing, and chewing does not extract a greater sensory experience from the soup than simply holding it in the mouth. Salad, on the other hand, would be chewed before swallowing under normal circumstances, and the act of chewing will change the texture and consistency of the food (thus stimulating haptic senses), and also increase the flavour by releasing more tastants and flavour into a vapourous state, enabling more intense stimulation retronasally.

Some experimental results indicate that SSS is closely related to ratings of prospective consumption, and actual consumption of the Eaten food. Sensory-specific satiety results in decreased consumption of the Eaten food but not the Uneaten foods (B. J. Rolls, et al., 1981; B. J. Rolls, et al., 1984). However, there are some instances where ratings of prospective consumption have differed to observed consumption (e.g. Hetherington, et al., 2002).

1.2.1.2. Sensory-Specific Satiety in Non-Human Animals

Sensory-specific satiety is not a purely human phenomenon - evidence suggests that both rats and non-human primates experience this effect, and it is likely to extend to other species too.

Early work on SSS can be said to be derived from a study by Jacques Le Magnen (English translation of original 1956 publication, 1999), in which rats were exposed to a synthetic diet, each day paired with one of four different odours. Exposure duration was limited to two hours at the same time every day, and the exposure phase lasted for 32 consecutive days. After the exposure phase, rats entered the testing phase, in which they were offered the same synthetic diet every 48 hours, but the odour-pairing was switched between the four odours every 30 minutes during the 2-hour feeding period. On intervening days, feeding reverted back to a single odour-paired food for the 2-hour duration. Intake was measured at 30-minute intervals throughout all feeding sessions during the testing phase. Overall intake was greater for the days in which the rats were offered a varied diet. Initial intake after the first 30 minutes was similar for both the varied and monotonous feeding sessions, and this declined sharply for subsequent intake when the monotonous diet was consumed. When the varied food was offered however, intake remained high for the second 30-minute session after the food was changed. Intake after the fourth and final 30-minute session was comparable between varied and monotonous food presentations. These results suggest that the varied odours stimulated intake, and as the caloric and

nutrient composition of the food was identical, this stimulation must have been sensory, and dependent only on the changing odour. The decline in intake observed after 30 minutes for the monotonous food presentations would suggest that the rats had entered a state of general satiety by that point. Renewed consumption when presented with an alternative odour-paired food would appear to be an expression of SSS.

In a series of four experiments, Mook, Kushner & Kushner (1981) demonstrated that hungry rats initially satiated on a saccharin solution would subsequently continue to feed when offered powdered chow, milk, or a glucose solution. Satiation for the saccharin solution can reasonably be interpreted as sensory-specific rather than a general satiety: saccharin is not broken down by digestion in rats (nor in humans), releasing no energy upon consumption and therefore satiation is not derived from caloric satiety. Furthermore, if general satiety had taken place, the rats would not have resumed feeding when offered the alternative foods. Mook *et al* use the term 'oral satiety' to refer to the rats' rejection of further saccharin solution post-consumption, and observed that the rat consumes a fixed amount before ceasing feeding. This could well translate to SSS developing over this period of time - the fixed amount possibly reflecting a sensory-satiety value that is specific to the saccharin solution. Mook *et al* suggest that the oral satiety observed in these experiments was not due to hedonic adaptation; though they use this phrase to refer to what apparently equates to sweetness-satiety, rather than a general decline in experienced pleasantness relating to the consumption of the saccharin solution. This is supported by the fact that the rats would return to consume further saccharin solution, but only if the concentration was greater than the initial solution on which they had become satiated. Mook *et al* point to gustatory-adaptation as a possible explanation: that taste input fades, in line with consumption, until it reaches a point where it no longer stimulates ingestion of that food. Although the authors are clear that they are not suggesting this adaptation occurs at receptor level, it would be likely that this is the case (see Section 1.2.3: Putative Mechanisms Sensory-Specific Satiety).

A similar study from the same laboratory presents a sequence of three experiments where concentrated glucose solution was used instead of saccharin solution (Mook, et al., 1983). Rats in a state of hunger drank the glucose solution to satiety, but returned to feeding when offered powdered or pelleted chow, or powdered glucose. This study provides more evidence for increase in consumption when a varied diet is available. In another experiment, Berridge (1991) allowed rats to become satiated on either milk or a sucrose solution, and then measured taste-reactivity to either of these liquids. Caloric

satiety reduced hedonic reactions to both fluids, but the reactions were further reduced when the rats tasted the same liquid on which they had become satiated. This evidence suggests that the further decline in expressed liking for the consumed liquid was related to the taste of the liquid, and was therefore an expression of SSS. Further experiments have shown that SSS can be induced in rats in the laboratory (e.g. Ahn & Phillips, 1999; Dwyer, 2005; Woolley, Lee, Kim, & Fields, 2007).

Taste reactivity in monkeys is expressed by behaviours that can be represented in two clusters: those that indicate either an acceptance of a food (e.g. reaching toward the food, mouth open), or a rejection of a food (e.g. pushing the food away, closing the mouth). When presented with palatable food, the initial responses are accepting behaviours, but during consumption the behaviours progressively change towards those signalling rejection (E. T. Rolls, Murzi, Yaxley, Thorpe, & Simpson, 1986). Often, when a new food is subsequently presented, the behaviours revert to indicating acceptance of the new (Uneaten) food, and the decline in acceptance of the previously consumed (Eaten) food is attributed to sensory-specific satiety (E. T. Rolls, et al., 1986). Edmund Rolls' laboratory (for reviews see 2005, 2006) has repeatedly induced SSS in non-human primates (predominantly macaques), and much of this research points to SSS arising from neuronal habituation in the prefrontal cortex. In addition, Kringelbach (2000) specifies the orbitofrontal cortex as the locus of SSS for the flavour of a food in non-human primates. The neuronal evidence for SSS is discussed in Section 1.2.3: Putative Mechanisms Sensory-Specific Satiety.

1.2.1.3. Critique of Sensory-Specific Satiety

Tests for sensory-specific satiety, as defined and discussed so far, and as used in the experiments in this thesis, rely on measurement of pleasantness ratings for both the food that has been consumed (the Eaten food) and other comparison foods that are evaluated but not consumed (the Uneaten foods). As such, it is assumed that ratings of pleasantness reflect liking for the food, and that SSS is a decline in liking for the Eaten food when compared to the Uneaten foods. However, there is some argument for a distinction between the pleasantness of the *taste* of the food ('liking'), and the pleasantness of the *act of eating* the food ('wanting') (Rogers, 1990), a distinction that is not readily assessed using pleasantness rating scales. Rogers defines palatability as the result of an aggregation of post-ingestive signals with stimuli experienced during consumption of that food, an assertion that is supported by Berridge (1996). Rogers argues that palatability is the

hedonic quality of the food, and not associated solely with the sensory aspects of the food. If this is the case, pleasantness ratings, as used to measure SSS, may reflect an immediate, short-term decline in 'wanting', rather than purely 'liking' as first assumed.

Berridge (1996) goes further in identifying the differences between liking and wanting. 'Liking' is described as the palatability of a food (in line with Rogers, 1990), and 'wanting' as the appetite for the food. Traditional views might suggest that reward is what we *feel* it is, and something that only humans can articulate, because it is subjective. With animals, we can observe different responses that indicate liking and wanting, but we cannot, as yet, ascertain an animal's subjective experience. Berridge suggests that reward can exist outside of this subjective experience, and is in agreement with Rogers (1990), in describing palatability reward as encompassing the physiological state associated with liking. Mela (2001) asserts that liking is an affective perception of the stimulus, is linked to the present, and associated with contexts that may include not only the current situation, but the beliefs and expectations that the individual holds about the stimulus. Therefore, liking is subject to variability that is connected to context: when the context changes, so too may the magnitude of liking, even though the stimulus remains the same. These descriptions come very close to defining the associations acquired in both flavour-flavour learning (FCL), and flavour-consequence learning (FCL) (see Section 1.3.3: Dietary Learning).

Crucially, Berridge's (1996) definitions offer alternative ways of conceiving of 'wanting' and 'liking', different from the meanings assigned to these words in everyday use. 'Wanting', as the equivalent of appetite, is a disposition to eat the food in question, and a motivational factor. 'Liking', as palatability, is the sensory pleasure of eating the food in question, and is an affective state. Wanting and liking usually co-occur, but they are mediated by two separate brain mechanisms (for a review of the evidence, see Berridge, 2004). In fact, behavioural studies on animals have offered clear methods of differentiating between wanting and liking. Human infants, chimpanzees, mice and rats produce similar facial expressions to indicate liking (of sweet tastes) and disliking (of bitter tastes) when food is consumed. These responses are expressions of affect, and are unrelated to wanting. Instrumental measures, on the other hand, provide evidence of appetite for the food, by measuring how much an animal is prepared to work for the food reward. Peciña *et al* (2003) for example, present evidence of this dissociation. In this study, DAT knock-down mice (with reduced dopamine transporter levels, resulting in increased levels of dopamine in the brain, compared to wild-type mice) were faster and

less prone to distraction in a runway task with a food reward. However, the same mice showed no significant increase in liking for the same food reward when orofacial expressions were measured during taste tests. Put simply, the mice with increased dopamine levels exhibited increased wanting but not liking, for the same food reward. In humans, elevated dopamine levels have also been shown to correlate closely with ratings of wanting (measured as self-reported 'hunger' and 'desire for food'), but not liking (Volkow, et al., 2002), reinforcing the body of evidence for separate neurological mechanisms.

An important factor in defining the wanting vs. liking argument is the element of awareness. Both wanting and liking can be experienced consciously or unconsciously (Berridge, 2004). In the incentive salience model, wanting is not necessarily conscious, even when triggered by a stimulus, because often the stimulus does not require conscious processing. In this instance the 'wanting' (which may be described as yearning, or an 'urge') is cue-triggered, perhaps by the contextual landscape that, through repeated exposure, has become associated with the stimuli. An example of this is increased 'wanting' for narcotics, experienced by addicts, and triggered by viewing drug-taking paraphernalia. In reverse, changes in liking may occur without the individual becoming aware of the change. Berridge (2004) gives the example of an experiment on humans, where images of happy or angry facial expressions were presented to participants for a period of time that was too short for the participants to have been aware of seeing the stimuli. Immediately afterwards, those that had been subjected to the happy facial expressions drank more of a fruit drink, and rated the pleasantness as greater than did those that had viewed the angry expressions. The critical observation here, is that neither group reported feeling more positive or negative afterwards when completing mood ratings. Therefore the change in affective response to the drink was not mediated by subjective feelings, but by an unconscious affective reaction to the facial expressions. This evidence supports Berridge's (1996) assertion that reward can exist outside of subjective experience, and without awareness.

In response to the arguments raised by Berridge, by Rogers and by Mela, a more recent study by Havermans, Janssen, Giesen, Roefs, & Jansen (2009) examined the extent to which SSS is a reflection of decline in liking or wanting. Participants tasted chocolate milk and crisps, rating each for pleasantness of taste and smell (as a measure of liking), then consumed a 250ml portion of the chocolate milk. Post-consumption ratings of both foods illustrated successful induction of SSS - with the chocolate milk declining in

pleasantness to a greater degree than the crisps. Immediately after testing, participants played a computer game for points that could be exchanged for food reward (either the chocolate milk, or the crisps, in a between-subject design). Points were awarded on a fixed ratio schedule, in progressively greater ratios, and participants could cease playing at any time. Participants who were rewarded with crisps made a significantly greater number of responses than those that were rewarded with chocolate milk, indicating a lower degree of wanting in the chocolate milk condition. In addition to this, post-consumption pleasantness ratings from the SSS test were correlated with the number of points obtained during the subsequent game. This evidence indicates that although measures of pleasantness may well reflect wanting as well as liking, both measures decline in parallel during SSS manipulations, and therefore SSS may be an expression of decline in both wanting and liking.

In summary, there is sufficient evidence to demonstrate that wanting and liking can be changed by separate processes, mediated by separate brain mechanisms, and dissociated with careful experimental manipulations. There are a few dissenting voices in regard to what we measure when we conduct SSS experiments. Berridge (1996) points out that many studies equate the selection (choice) and consumption (acceptance) of food, to wanting. Measures of liking and wanting would adequately substitute for each other if this is true, and usual measures manipulate both liking and wanting together, a criticism that can be squarely levelled at the study of SSS. Mela (2001) agrees that many SSS tests don't provide the opportunity for separately measuring wanting from liking, and in these instances, changes to pleasantness ratings may reflect motivational changes (i.e. a decline in wanting) in the immediate context in which the food is presented. Scales of 'liking' or 'desire to eat' may not be refined enough to measure the distinction between wanting and liking, especially for unconscious wanting (Mela, 2006).

In SSS experiments, pleasantness ratings are assumed to assess liking, though may also measure wanting. 'Desire to eat' scales are assumed to assess wanting, but equally may also measure liking. Evidence from Havermans, Janssen, *et al* (2009) indicates that SSS may represent a decline in both wanting and liking, and therefore motivation and affect. Therefore, because wanting and liking are usually parallel in most situations (including SSS manipulations), evaluations of 'pleasantness' in human SSS experiments - though they represent both wanting and liking - are nevertheless useful in measuring the phenomenon of pleasantness decline during food consumption.

1.2.2. Factors Influencing Sensory-Specific Satiety

1.2.2.1. Taste Perception Deficits

Several factors influence taste perception in general, and therefore by extension may influence the development of SSS in particular. Although we often experience flavour as a single sensation, it is a composite perception, subject to input from multiple sensory modalities, primarily (but not limited to) those of taste (from the mouth) and olfaction (from the nose). Integration of the various senses occurs at a neuronal level in the areas of the brain that process chemosensory information, and results in a unified representation on a cognitive level (for elegant reviews see Reed, Tanaka, & McDaniel, 2006; E. T. Rolls, 2005; Small & Prescott, 2005)

Since SSS appears to operate due to some form of habituation to the hedonic quality of the sensory experience of food in the mouth, or indeed even just to repeat exposure to the smell of a food (e.g. E. T. Rolls & Rolls, 1997), it would be predicted that any factor that influences sensory perception of foods would modify SSS. Some medications (for example diuretics, antidepressants and antimicrobials) disturb olfaction and taste sensitivity (e.g. Abbott, 1997; Doty & Bromley, 2004; Hays & Roberts, 2006).

Compounds in cigarette smoke (e.g. Formaldehyde) are known to create long-term (but reversible) defects in olfaction, and alcohol can reduce the perceived intensity of flavours, even after detoxification (Doty & Bromley, 2004). Any suppression of flavour perception, either by inhibiting taste, or by inhibiting olfaction, will suppress flavour perception, the majority of which is received retro-nasally (to the nasal cavity via the throat, rather than the nostrils), whilst food is being masticated in the mouth. Deficits to olfaction and taste may reduce sensitivity to sensory-specific satiety by diminishing the impact of the sensorial characteristics of the food being eaten.

1.2.2.2. Individual Differences

The influence of individual differences on SSS are important when considering the selection of human participants for research, and for extrapolation of experimental results from participant samples to the general population.

The effect of medications on the chemosenses may be compounded with ageing, as multiple medications are commonly prescribed to the elderly (consideration is given to the effect of medications on SSS in Section 1.2.2.1: Taste Perception Deficits). Yet ageing

itself results in deficits to taste and olfactory sensitivity (Hays & Roberts, 2006). Research conducted by Essed, et al. (2006) tested the effect of repeated consumption of a beverage over 12-day periods on consumption, pleasantness and boredom. Results revealed that the elderly (age > 65 years) women's ratings of pleasantness and boredom did not change over this period - most likely due to decreased chemosensory sensitivity as a result of ageing. A reduction in taste sensitivity will result in a parallel decline of sensory-specific satiety. In one study, those above the age of 65 years showed no sensory-specific satiety at all, when measures of the 'pleasantness of taste' were used to test for SSS (B. J. Rolls & McDermott, 1991), yet measures of desire to eat (DTE) did decline after consumption. Further research conducted by Hollis and Henry (2007) with another sample of elderly participants (mean age of 72 years old) confirmed that SSS was significantly reduced in this age group, and increasing the intensity of the flavour (of strawberry yoghurt) did not seem to compensate for the apparent sensory loss.

There is no reliable evidence that sensory-specific satiety differs in magnitude or onset between the sexes: indeed many studies demonstrate similar responses between males and females (e.g. Brondel, et al., 2007; Guinard & Brun, 1998; Miller, Bell, Pelkman, Peters, & Rolls, 2000; Vandewater & Vickers, 1996).

Equally, SSS does not appear to be affected by Body Mass Index (BMI). Snoek *et al.* (2004) found no differences between normal-weight and obese women in their sensitivity to SSS, and the results were the same for testing in a lunch context (sandwiches) as well as a snack context. Brondel *et al.* (2007) provided further evidence of similar SSS responses across the BMI spectrum and between sexes.

Eating disorders affect sensory-specific satiety in different ways, regardless of BMI: Bulimics may not exhibit sensory-specific satiety, and anorexics display sensory-specific satiety with much smaller portions than those without eating disorders (Hetherington & Rolls, 1989; B. J. Rolls, et al., 1992).

Dietary restraint, where an individual consciously restricts food intake, does not appear to have an impact on the magnitude of sensory-specific satiety. The majority of evidence suggests that pleasantness reduction as an expression of SSS does not differ between restrained and unrestrained eaters (B. J. Rolls & McDermott, 1991; Snoek, et al., 2004; Tepper, 1992).

1.2.2.3. Energy and Macronutrient Content

The decline in pleasantness of the Eaten food in sensory-specific satiety is generally accepted to be unrelated to energy or macronutrient content: the majority of experimental findings in the literature show that neither energy intake nor macronutrient composition significantly influence the degree of pleasantness decline during consumption, and present a strong argument that magnitude of sensory-specific satiety is reliant solely upon sensory cues. However, there is some evidence to the contrary, leaving open the possibility that protein content may influence pleasantness ratings under certain conditions.

Experimental evidence demonstrates that SSS is unaffected by total energy intake (Atton, 2006); and by energy-density of the Eaten food, with both high- and low-energy density foods producing comparable degrees of SSS (Birch & Deysher, 1986; Miller, et al., 2000; B. J. Rolls, Hetherington, et al., 1988a; B. J. Rolls, Hetherington, & Laster, 1988). Further evidence provided by Bell *et al.* (2003) indicates that the volume of the food consumed, rather than energy content, is the better predictor of the magnitude of SSS. Bell found that doubling energy content of a liquid food (milkshake) whilst controlling for portion size, had no effect on the degree to which SSS developed, yet the magnitude of SSS was significantly increased by doubling the volume of the liquid food, while the energy and macronutrient content were held constant.

In contrast, Johnson and Vickers (1993) found that pleasantness ratings in the context of SSS, declined in line with increases in caloric content of the test food. However, the aim of the study was to explore macronutrient and flavour effects; energy differences were not the *a priori* focus of the experiment. Consequently, there was a considerable difference in portion size between the low- and high-energy Eaten foods, which is likely to have confounded the results. Although the findings demonstrated a greater decline in pleasantness after consumption of the high-energy food in comparison to the low-energy food, there are two other possible explanations for this finding. Firstly, the magnitude of SSS is greater when a larger volume of the same food is consumed, as demonstrated by Bell *et al* (2003). Therefore, the increased SSS in the high-energy condition may be a response to the volume consumed, rather than the energy consumed. The second possibility is that the greater decline in pleasantness for the larger portion was due to the onset of general satiety cued by sensations of stomach fullness and / or energy content.

Evidence for differential effects of macronutrients on the magnitude of SSS is more contentious. Relatively few studies have been published in this area, and conclusions are mixed, with some findings not replicated and others emerging by serendipity rather than by design.

Results from two experiments conducted by Snoek *et al.* (2004) into BMI and SSS indicated that high-fat foods induced greater sensory-specific satiety than low-fat foods, though ultimately taste (sweet vs. savoury) accounted for a significantly greater variation in pleasantness decline than the fat content. The observed effect of fat content on SSS was difficult to replicate in the second experiment, and so ultimately dismissed as spurious by the researchers. Using crisps as the test food, Miller *et al.* (2000) found no significant effect of fat-content (vs. a non-nutritive fat-replacement) on the magnitude of SSS, or rated pleasantness and other sensory properties.

There is a wealth of evidence that protein induces greater general satiety than carbohydrates, fat, or alcohol (see Reid & Hetherington, (1997) for a review of the methodology employed). Satiety in the following experimental contexts was measured either by self-report (e.g. ratings of hunger, fullness, gastric emptiness, or desire to eat) (Chung Chun Lam, Moughan, Awati, & Morton, 2009; Fischer, Colombani, & Wenk, 2004; Poppitt, McCormack, & Buffenstein, 1998), and / or by observed behaviour (e.g. caloric intake, weight of food consumed) (Bertenshaw, Lluch, & Yeomans, 2009; Chung Chun Lam, et al., 2009; Poppitt, et al., 1998). Veldhorst's (2008) review of protein-induced satiety concludes that acute protein-induced satiety (from both self-report and observational measures) has been observed with as little as a single meal, and with variations from 25% to 81% of energy from protein. Some of the SSS literature employs a paradigm of *ad libitum* consumption of the Eaten food, rather than a fixed portion. Under these conditions, high-protein foods may contribute more to SSS than foods high in carbohydrates or fat, as a result of general satiety.

The effect of protein on SSS has been studied by fewer researchers, and with opposing results. Rolls *et al.* (1988b) conducted SSS tests on female participants 2 hours after 5 preloads differing in macronutrient content. Sensory-specific satiety was reliably induced with all preloads with the exception of chocolate, though the magnitude of SSS did not differ between conditions. Hunger, fullness and food intake were affected differentially by macronutrients: both the high-protein and high-carbohydrate preloads resulted in significantly greater fullness ratings, lower hunger ratings and lesser subsequent intake

when compared to the high-fat, high-sucrose, and mixed preloads. The high-protein preload (chicken) produced the greatest decline in pleasantness ratings at both 2 and 120 minutes post-consumption. However, this trend for greater SSS with high-protein food did not reach statistical significance. Overall the findings support the accepted view that protein is more satiating than other macronutrients, but does not support protein as a significant modifier of SSS.

Johnson and Vickers (1992) also found that high-protein foods (turkey and cheese) were subject to the greatest decline in liking during consumption, but these foods were also the least-liked at the start of the experiment. In a follow-up study (1993), high-protein preloads resulted in a significantly greater decline in caloric intake at a subsequent meal than high-carbohydrate or high-fat preloads. Whilst again we find these studies provide evidence of protein being the most satiating of the macronutrients, caution should be employed in interpretation of the 1993 experiment: as previously mentioned, portion sizes were not controlled for, and are therefore a possible confound. Vandewater and Vickers (1996) set out to specifically test the effect of protein on SSS, with yoghurt and sandwiches, each served in a high- and low-protein format, matched for sensory properties and energy density. As with the studies above, the high-protein foods were found to be more satiating, measured in this instance by significantly greater fullness ratings against the low-protein foods. In addition, the high-protein versions declined in liking to a significantly greater degree than the low-protein foods, and these data were unaffected by the balance of carbohydrates and fat comprising the remaining energy content. This experiment, designed specifically to explore the effect of protein on SSS, offers clear evidence that high-protein foods result in greater magnitudes of SSS.

Returning to the study by Snoek *et al.* (2004), the experimental foods were sandwiches and snacks, selected for the properties of taste and fat-content. As an artefact of test food selection - or possibly by design - both experiments included a high-protein food in each of the high- and low-fat categories. In the first experiment, pâté (high-fat) produced greater decline in pleasantness as the Eaten food than any of the other sandwich fillings (chocolate spread; rose hip jam; roast beef). The pâté sandwiches also generated the greatest magnitude of SSS, measured as the difference in pleasantness changes between Eaten and Uneaten foods. The roast beef filling, however, produced the least decline in pleasantness, and of the four fillings, the lowest magnitude of SSS. Johnson & Vickers (1992) found that high-protein foods induce greater SSS than low-protein, and while results for the pâté sandwiches lend further support to this assertion, results for the roast

beef sandwiches do not. Snoek *et al* suggest that the unexpectedly low SSS response to the roast beef sandwiches may be explained as a consequence of the food's low taste intensity: the sandwich contained no condiments or other foods, and was therefore quite bland, especially in comparison with the other Uneaten foods. In the second experiment, the two high-protein foods (chicken fillet and cheese crackers) were second and third respectively in order of magnitude for the decline in liking post-consumption, and for SSS as measured as the difference in change in pleasantness between the eaten and uneaten foods. These results illustrate an unreliable effect of protein in these two experiments, but as noted already, this was not the aim of the study.

In conclusion, there is clear evidence that protein is the most satiating of the macronutrients, but not enough evidence to accept or reject the notion that high-protein foods produce greater SSS than high-carbohydrate or high-fat foods. Some findings emerged from experiments that were not designed to detect protein effects, and include possible confounds, and only one experiment reliably induced a greater magnitude of SSS from an *a priori* hypothesis. It is possible that a greater decline in pleasantness of the high-protein foods found in some of these studies may be due to anticipated post-ingestive satiety - a concept dubbed "conditioned satiety" by Booth (1972) (see Section Learned Satiety). To the extent that high-protein foods have sensory properties associated with the sensation of satiety imparted by those foods, then they may be susceptible to greater SSS as a result: the sensory aspects become cues for anticipated satiety, which in turn may be reflected as a greater decline in pleasantness ratings during SSS testing. One cannot conclude from the evidence presented here that protein does not affect the extent to which SSS develops, but if it does, the phenomenon appears to be unreliable and difficult to replicate at this time.

1.2.3. Putative Mechanisms Underlying Sensory-Specific Satiety

SSS as a phenomenon is suggested to be the result of 'sensory fatigue' (Hetherington, 1996), and can be observed at a neuronal level. Research has shown that not only can single neurones be shown to reduce responding to particular flavours, but also that dishabituation occurs in the same timescale as recovery from SSS is observed behaviourally. Much evidence is derived from work with non-human primates. Indeed, the neuronal habituation evidence for SSS can be seen with brain imaging, demonstrating habituation (of sorts) on a neuronal level (Kringelbach, 2000; E. T. Rolls, 2005, 2006; E. T. Rolls, et al., 1986).

1.2.4. Role of Sensory-Specific Satiety

SSS is likely to be a evolutionary adaptive response that increases food variety, and therefore nutritional balance (e.g. B. J. Rolls, 1986). A decline in pleasantness for an Eaten food, but not an Uneaten food, will lead an organism to consume a varied diet, where available. This mechanism works to promote nutritional balance in the diet, particularly important for omnivorous species, for whom there is no single food that provides the full range of nutrition physiologically necessary for good health. A decline in the pleasantness of an abundant food item that occurs before general satiety is reached, is likely to bring about behavioural changes that instigate alternative food seeking behaviour. In this way, the animal consumes a variety of foods within each meal, and the risk of malnourishment for the individual is reduced. As SSS in humans usually persists no further than an hour or two after a meal (see section 1.2.1.1: Sensory-Specific Satiety in Humans), the palatability of the abundant food will return to normal in time for the next meal.

Conversely, species that consume a single food (e.g. specialist herbivores such as pandas and koalas) may not be subject to SSS in the same way. Taking the koala as an example, at first glance SSS would seem to be a detrimental and maladaptive response for an organism that relies solely on one food (eucalyptus foliage) for their nutritional needs. Interestingly though, there is evidence that koalas are selective consumers of different species and varieties of Eucalyptus, and have been observed both in their natural habitat and in captivity to express clear preferences for some varieties over others. Variation occurs in the nutrients of the foliage of different trees, and in leaves of different ages (for a detailed review, see Moore & Foley, 2000). If koalas experience SSS, it is likely to be driven by sensorial differences in the different types of eucalyptus foliage, and as a consequence promote variety in nutrient intake, even within the narrow spectrum of food items that comprise their diet.

1.2.5. Summary of Sensory-Specific Satiety

Sensory-specific satiety can be defined as a sensorially-related reduction in pleasantness for a food as it is consumed. SSS is not confined to the pleasantness of the taste of food: it has also been observed for the pleasantness of the smell, texture and appearance of food (see Section 1.2.1.1: Sensory-Specific Satiety in Humans). Foods that are not consumed, are not affected by such pleasantness reduction, except to the extent that they share

sensory characteristics of the food that is consumed. In such instances, the unconsumed food may decline in pleasantness to a lesser degree than the consumed food, and this phenomenon is termed a 'transfer effect' (see Section 1.2.1.1: Sensory-Specific Satiety in Humans). SSS is related to the sensory qualities of the food, and not to the energy it imparts, though the putative effect of macronutrient content is unclear (see Section 1.2.2.3: Energy and Macronutrient Content). It is not necessary to swallow the food in order for SSS to occur (see Section 1.2.1.1: Sensory-Specific Satiety in Humans). SSS is at the greatest magnitude immediately post-consumption, and slowly returns to baseline thereafter, with full recovery within hours (see Section 1.2.1.1: Sensory-Specific Satiety in Humans). For these reasons, SSS is readily distinguished from general satiety. Neither gender nor BMI impact upon SSS, though ageing appears to be a factor in reduced magnitude, with SSS almost absent in the elderly (see Section 1.2.2.2: Individual Differences).

SSS has been shown to occur on the level of single neurones in the prefrontal cortex, that reduce firing in line with consumption: it is likely that SSS is controlled by neuronal mechanisms, though these may be more complex than we currently understand (see Section 1.2.3: Putative Mechanisms Sensory-Specific Satiety). SSS has been observed in humans, non-human primates, and rodents (see Sections 1.2.1.1: Sensory-Specific Satiety in Humans and 1.2.1.2: Sensory-Specific Satiety in Non-Human Animals), and it may be an adaptive response that promotes dietary variety, thus increasing the likelihood of the organism receiving adequate nutrition (see Section 1.2.4: Role of Sensory-Specific Satiety).

1.3. Long-term Changes in Food Pleasantness

1.3.1. Mere Exposure and Monotony

1.3.1.1. *Mere Exposure*

Zajonc (1968) identified the phenomenon of "mere exposure", whereby repeated exposure to a novel stimulus may result in an increase in liking over time, providing that the stimulus is not associated with a negative consequence. Zajonc states that in the absence of reinforcement, familiarity alone is sufficient to enhance an attitude towards a novel stimulus. The mere exposure process may work either by enhancing a positive attitude, or by reducing a negative attitude, such as may be the result of neophobia (fear of novelty). Bornstein (1989) suggests that attenuation of neophobia responses may well arise from exposure to the novel stimulus that does not result in negative consequences. The predicted outcome being that the organism will approach the same stimulus less cautiously on future exposures. This detail may provide a useful distinction between associative learning, and a general remembering of previous events. Even though mere exposure effects do not rely upon learned associations, there can be no certainty that some form of arbitrary learning has not taken place during the course of exposure to the novel stimulus. Exposure itself is a necessary criterion of learning, and it is likely that exposure may provide the basis for hedonic changes that are the result of subsequent learned associations with the same stimulus. Mere exposure is sometimes ascribed as a *post hoc* explanation for changes in liking, and exposure to new foods (at least in humans) is seldom without contextual cues, such as the feeding situation and cultural expectations (Mela, 2001). Ultimately, there is no way to ensure that some form of learning has not taken place during the course of exposure to novel stimuli, as a context-free environment is a practical impossibility, and a predisposition to acquiring associations between stimuli and reinforcement is a highly adaptive trait of most animals.

Zajonc's (1968) theory of mere exposure is based on studies investigating correlations between frequency and attitude (or preference) for words, letter pairs, and photographs (notably all visual stimuli). Correlational studies alone do not provide sufficient evidence of cause and effect. This, coupled with the absence of food-related stimuli in the studies, means the evidence would be best interpreted with caution. However, Zajonc presumes that the effect of exposure on attitude is generic, and this being the case, it follows that

the effects of mere exposure may be elicited with food stimuli too. Interestingly, Zajonc observes that exposure effects seem not to be related to the frequency of exposures, but to the logarithm of exposure frequency, and concludes that mere exposure effects will probably be greater for novel, rather than familiar stimuli. This argument becomes important when assessing experimental evidence for mere exposure to foods, and whether the stimuli tested are novel or already familiar to participants.

Whilst there is much evidence for mere exposure effects in general (see Bornstein's (1989) review), there are fewer experiments specifically testing mere exposure effects with food stimuli in humans. In one such study, Pliner (1982) had participants taste each of four novel fruit juices a different number of times (20 exposures; 10 exposures; 5 exposures; not-tasted). Immediately post-exposure, liking ratings increased in line with the frequency of exposures, in a monotonic relationship that is contrary to Zajonc's (1968) observations. On a subsequent and final session, liking ratings were again measured as a function of the number of exposures in the previous session (though the range of liking ratings was greatly reduced). The evidence assessed by Zajonc indicated a log-frequency-of-exposure to liking ratio, where the effects are greater and more salient for fewer exposure frequencies than for many. Therefore, as Zajonc concedes, the mere exposure effect is more readily observed for novel or near-novel stimuli, and may be hardly detectable for familiar stimuli. Pliner's results, on the other hand, are based on purely novel stimuli, and show a clear 1:1 relationship between exposures and liking, though in that experiment, 20 exposures was the maximum tested. The monotonic relationship between exposures and liking in Pliner's data may be because up to 20 exposures has not been sufficient for the novel drink to become very familiar, and this may have been compounded by the fact that all exposures took place in a single session, rather than on multiple occasions. This would explain why the data failed to fit the log-curve observed by Zajonc: 20 exposures could be considered low frequency, and the lower end of the log curve can closely resemble a monotonic relationship.

However, Pliner's study was not alone in recording a monotonic relationship between exposures and liking. Further studies of the mere exposure effect with food stimuli in humans (e.g. Crandall, 1985; Stevenson & Yeomans, 1995) produced results showing that the attitude towards the food stimuli increased as a function of the frequency of exposures. Crandall (1985) found that average per-person consumption of doughnuts increased in line with the number of exposures (up to thirteen), providing evidence for the effect of mere exposure with a non-novel stimulus. Rather than being laboratory-

based, this study was conducted in free-feeding conditions. Participants were workers in a cannery in Alaska where all meals were provided on-site by their employer, and the doughnuts were presented intermittently (on average just over every two days) as an option during morning tea breaks. The participants were unaware that their eating behaviour was being observed, and usual mealtimes and location were no different to their regular routine.

Stevenson & Yeomans (1995) demonstrated mere exposure effects for the burning sensation produced by capsaicin (the 'hot' compound found in chilli peppers) over the course of five exposures in a laboratory-provided meal. Liking ratings increased linearly with the number of exposures, and were not related to familiarity of (and therefore prior exposure to) the chilli burn sensation. The theory that variety in the magnitude of response during exposure may in some part be an individual difference, was explored by Tuorila *et al.* (1994). Participants were classified as either food-neophobics (fearful / avoidant of novel foods) or food-neophiliacs (inclined to a positive approach to new foods), and exposed to novel foods, with a follow-up eight weeks later. As one might expect, the neophobics rated novel foods less favourably than the neophiliacs. However, initial negative responses to the novel foods were reduced, at least in part, by exposure. Curiously the neophobics seemed resistant to these effects, as liking ratings for the novel food subsequently decreased.

Repeated 'mere' exposure (that is, exposure without obvious reinforcement) can lead to satiation. For example when a word is repeatedly spoken aloud, it may seem to lose meaning to the speaker, a phenomenon referred to as semantic satiation, and indicated by a move towards neutrality on bipolar semantic differential scales (e.g. good/bad; strong/weak). Zajonc's (1968) experimental words were initially rated below neutral (i.e. negatively), and were rated more positively after 25 exposures. The reduction in polarity for the exposure words actually represents a positive shift in attitude as a result of mere exposure, rather than a shift towards the negative, which would be expected in a satiation model (for example in alliesthesia, SSS, or boredom).

Another human factor that may modulate the mere exposure effect is that of propensity to boredom, or monotony. For the purposes of this thesis, monotony is defined as a decline in affect, or attitude to a stimulus after multiple exposures (in the absence of obvious reinforcement). A series of experiments tested boredom-prone and non-boredom-prone participants viewing novel visual stimuli (Bornstein, Kale, & Cornell, 1990). The results

demonstrated that the boredom-prone participants showed no susceptibility to mere exposure effects, yet non-boredom prone participants did. Interestingly, complex stimuli produced greater mere exposure effects than simple stimuli, a difference which was amplified when both stimuli were viewed (resulting in an increase in affect ratings) rather than just one (resulting in a decrease in affect ratings). These findings seem to indicate that an available comparison increases the exposure-induced magnitude of change in affective response to a novel stimulus; and that viewing a single novel stimulus is more likely to result in monotony, than in the mere exposure effect. In fact, the authors suggest the results support the two-factor model, generating a biphasic curve when affect ratings are plotted against exposures. Initially liking increases in line with the frequency of exposures (plotting mere exposure effects) until a boredom threshold is reached, at which point affect then decreases with further exposures (plotting a boredom, or monotony effect). Bornstein (1989) suggests that from an evolutionary perspective, these responses are adaptive, for example: in the event of multiple exposures without reinforcement, boredom would motivate an organism to move on to more rewarding foods.

1.3.1.2. Monotony

Whilst monotony and sensory-specific satiety both result in a reduction in rated pleasantness of the consumed food, there are some differences between them. SSS occurs during consumption, within a single exposure, and hedonic responses recover within a couple of hours of eating. Monotony, on the other hand, occurs after either a prolonged exposure, or multiple exposures to the food stimulus, and may persist for days, weeks or even longer. The findings of one study indicate that a single prolonged exposure to cheese biscuits (eaten to satiety) was sufficient to decrease appreciation up to a week later, but the same effect was not observed for pears in syrup (Weenen, et al., 2005).

Whereas SSS results in reduced intake of the Eaten food (B. J. Rolls, et al., 1981), and whilst monotony also reduces the rated pleasantness of the food, subsequent intake of the stimulus food appears completely unaffected (Hetherington, et al., 2002). In this experiment, repeated exposure to chocolate reduced rated pleasantness and desire to eat, but not intake. Interestingly, bread and butter was not subject to a pleasantness reduction under the same repeated exposure conditions. A high level of initial pleasantness does not appear to slow the onset of monotony, and there seems to be no difference between fixed or variable frequencies of consumption in monotony development (Hetherington, et al., 2002). In another study, chocolate successfully induced monotony for rated

pleasantness and preference, and also reduced frequency of consumption, yet chips consumed under the same conditions elicited no such effects (Hetherington, et al., 2000).

Meiselman *et al.* (2000) studied monotony in the form of repeated exposure to the same meal for five consecutive lunches. As expected, food acceptance declined over the course of the week, in line with levels of consumption, demonstrating the monotony effect. A contrasting experimental condition providing variety over the same five lunches resulted in no such effect, even though the first and final lunches were the same. In this experiment, one component of the monotonous lunch (gravy) was found not to decline in pleasantness over time, in comparison to the other components, and the meal as a whole.

It seems that some foods are resistant to pleasantness decline, and Meiselman *et al.* (2000) suggest that this applies more to staple foods. Experimental findings certainly seem to support this assertion, with no significant reduction in pleasantness found for bread and butter (Hetherington, et al., 2002); buttered roll (Johnson & Vickers, 1992); gravy (Meiselman, et al., 2000); and chips (Hetherington, et al., 2000). However, this does not explain why pears in syrup (Weenen, et al., 2005) are also subject to this effect. It seems reasonable to accept that staple foods would be resistant to consumption-related pleasantness decline. Such a response would be adaptive, guarding against undernourishment at times when the variety of food items is limited, albeit artificially.

This phenomenon could explain the results from Pelchat and Schaefer's (2000) research. In this experiment, a monotonous diet was given to participants for five consecutive days. During this time, they could consume nothing but a vanilla-flavoured liquid food, and water. The liquid food was nutritionally complete, and as participants did not lose weight during the course of the 5-day study, the researchers took this to indicate sufficient nutrition, and therefore consumption. It could be argued that had the study persisted for a longer period of time, the potential for observing weight loss among participants would be increased - five days may be an insufficient basis from which to predict longer-term weight changes on such a diet. The prediction was that the monotonous diet would result in a decline in liking for the liquid food, but this was not the case. There was no significant change in liking for the food over the course of the monotony period: the food was resistant to pleasantness decline at a time where variety of food was limited.

It is understood that individuals are generally unaware of experiencing SSS, as it is a purely hedonic response, and therefore occurs subconsciously (Hetherington, 1996).

However, Hetherington *et al.* (2002) do state that individuals are very aware when they are experiencing monotony, as it is a cognitive response to a hedonic change, and therefore the result of conscious processing. Mook and Votaw (1992) agree that a hedonic shift is not salient, but that it is accessible on introspection. The act of introspection is a cognitive process, and as such would bring pleasantness changes into consciousness, as in the case of monotony, thus supporting Hetherington *et al.* (2002).

1.3.2. Mere Exposure, Monotony and Sensory-Specific Satiety

To date, the effect of mere exposure on SSS had not been specifically tested. However, there have been studies to test the effect of repeated exposure in general, and monotony in particular, on the magnitude of SSS. In one of these (Hetherington, *et al.*, 2000), researchers found that monotony had no effect on SSS. Having said that, this study used chocolate as the stimulus, which was not a novel food to the participants. Another experiment investigated the effect of limiting snack food variety on intake over a nine-week period (Raynor, *et al.*, 2006). Monotony, the form of declining hedonic ratings, was present for the reduced variety group. Ratings for the chosen snack were lower than the other snack foods at the end of the study, which the authors suggest was 'long-term SSS'. This appears to defy the accepted definition of SSS as a short-term hedonic change that occurs during consumption and recovers afterwards. Once again, the exposure food was not novel to participants. In fact, in this experiment, participants were expressly required to select a snack food that was "...highly liked, commonly eaten (i.e. at least once per week)..." (Raynor, *et al.*, 2006 p.3).

Both mere exposure and monotony act to alter hedonic responses to a stimulus, yet with opposing results on the valence of the attitude change. Mere exposure increases the rated pleasantness of a food stimulus post-exposure, whilst monotony reduces rated pleasantness. It is reasonable to assume that each might have differential effects on the development of SSS, as a result of higher or lower baseline pleasantness ratings attributable to the multiple exposures.

1.3.3. Dietary Learning

The final two experiments in this thesis are concerned with three types of learning in relation to food consumption: flavour-flavour learning (FFL); flavour-consequence learning (FCL); and learned satiety. The essence of dietary learning is an acquired association, either between two stimuli (classical or Pavlovian conditioning), as is the

case with FFL and FCL, or between a behaviour and a consequence of that behaviour (operant or instrumental conditioning), as is the case with learned satiety. The distinction between classical and operant conditioning can be simplified: classical conditioning results in a modification of responding behaviours that are elicited by stimuli, whereas operant conditioning results in the modification of voluntary behaviours, and is maintained by the consequences of those behaviours.

Flavour-based learning includes both FFL and FCL, and results in acquired liking or disliking of the CS food, which acts as a precursor to the formation of food preferences and aversions. Learned satiety is the acquired control of meal-size during either the current, or a subsequent eating episode, and develops after an association is made between the US food and the energy it imparts post-ingestion. Given the importance of dietary learning, in particular FFL and FCL, to the overall aims of this thesis, the following sections explore in more detail the evidence for, and nature of, these forms of dietary learning.

1.3.3.1. Flavour-Based Learning

A learned liking for novel foods can be established through exposure to those foods, providing the food stimulus becomes associated with a contingent and congruent stimulus (as in FFL) or post-ingestive consequence (as in FCL). In FFL, repeated pairings of the novel food stimulus (CS) with the known food stimulus (US) results in transference of the hedonic valence from the known food (UR) to the novel food (CR). In FCL, the US is a physiological consequence of consuming the CS. Preferences and aversions acquired through FCL can result in behavioural responses that are oriented either towards (anticipation of reward), or away from (avoidance) the CR. As such, FCL may be expressed in terms of operant conditioning, but the initial associations are formed during a classical conditioning process.

Unlike flavour-flavour learning, flavour-consequence learning can develop without contiguity: an association between consuming the CS and experiencing the consequences of consumption can be formed over a time delay. This is most strongly observed in the case of acquired food aversions, where an unpleasant post-consumption experience, such as illness caused by food poisoning or allergy, can have a very long-lasting effect on the hedonic valence of the food that caused the illness (and indeed other foods consumed at the same time). Even if the subsequent illness is distanced in time

from consumption of the food by several hours, the association may still be reliably formed over the delay, and food aversions may occur after only a single incident, and persist for months or even years.

Both FFL and FCL have been successfully and reliably induced in humans under laboratory conditions. For example, Brunstrom *et al* (2001) presented participants with three novel drink flavours (coconut/fruity, apple/spicy, and bitter/lemon), each reinforced on a different contingency reward schedule for 30 trials (90%, 50% and 10% of the time). Participants chose their own confectionary reward at the start of the experiment, which was subsequently used as the reinforcer throughout the learning phase. After conditioning, participants rated the pleasantness of the drinks on a bipolar scale. The results showed direct correlation between reinforcement ratio and rated pleasantness of the cue flavour, indicating FFL had occurred. However, this was true only of participants with a low restraint score on the Dutch Eating Behaviour Questionnaire (DEBQ-R). The responses of the Restrained eaters were contrary to those expected if FFL had taken place, and ratings for the three flavoured drinks were similar for this group, regardless of contingency ratio. These findings suggest that highly restrained eaters may not be sensitive to the reward manipulation in the FFL paradigm.

A replication of the Brunstrom *et al* (2001) experiment, with minor differences, was published by the same laboratory in 2005 (Brunstrom, Higgs, & Mitchell, 2005). In this instance chocolate was used as the reinforcer for three different novel fruit-based drinks during 30 trials. Unrestrained eaters showed a post-conditioning preference for the flavour that was paired with reward on 90% of trials, indicating FFL, whilst restrained eaters tended to show a preference for the 10% flavour. These findings confirmed dietary restraint as a good predictor of dietary learning, with restrained eaters seemingly not susceptible to FFL. Based on this evidence, Brunstrom *et al* suggested that restrained eaters may experience the US (in this instance, chocolate) as unwanted, rather than as a reward. Therefore the hedonic valence transfer from CS to US may well be taking place - but for restrained eaters the valence is neutral, or possibly negative, resulting in a failure to increase liking. Experiment two (Brunstrom, *et al.*, 2005) paired visual stimuli with sweet taste on similar reinforcement scales. Restrained eaters reported a relative increase in liking for the 10%-paired image, whilst unrestrained eaters showed increase in liking for the 90%-paired image, confirming a positive valence transfer. These results confirm differential responding to FFL conditioning between restrained and unrestrained eaters. Furthermore, they suggest that restrained eaters do exhibit transfer of hedonic valence

from the US to the CS, even when the CS is a non-food stimulus. Overall, the evidence supports the assertion that sweet food reinforcers fail to act as a reward for restrained eaters.

In a later study, Brunstrom and Mitchell (2007) created two novel desserts, chocolate- and fruit-flavoured, made from yoghurt and jelly. Two versions of each dessert were developed: high- (HED) and low- (LED) energy density, similar in taste and appearance. Participants consumed the LED and HED versions on alternate non-consecutive days over six exposures, and rated intermediate-energy-density versions of the desserts for liking pre- and post-training. Unrestrained eaters (assessed by a post-hoc median-split on DEBQ-R scores) developed clear FCL, measured as a significant post-training increase in liking for the HED-paired dessert flavour. HED and LED desserts were almost indistinguishable in flavour, texture, and appearance, and pre-and post training ratings were taken for the intermediate-energy-density version. Therefore, differential liking responses arose from the learned association between the CS flavour and the US post-ingestive consequences of consumption (FCL), as distinct from a learned association between the CS flavour and another US flavour (FFL). Restrained eaters' responses, however, showed an increase in liking for both the LED and HED desserts post-training, with no evidence of differential responding between the two. This pattern of results confirms that restrained eaters exhibit unreliable changes to liking in response to both FFL and FCL paradigms. As a consequence of these works, most researchers now exclude highly restrained eaters from participating in flavour-based learning experiments, and to this end use either the DEBQ-R or the Three Factor Eating Questionnaire restraint scale (TFEQ-R) as screening tools.

Further studies of FFL and FCL also provide evidence that learned flavour preferences can be strengthened by motivational or appetitive state, during both acquisition and expression phases of learning. Caffeine lends itself well a CS in FCL, as its effect is due to negative reinforcement - the reward being the alleviation or reversal of unpleasant symptoms experienced during abstinence, akin to withdrawal. Participants in one experiment expressed higher liking for caffeine-paired cue flavours, against flavours not paired with caffeine, but the effect was dependent upon habitual high-caffeine use at baseline (Tinley, Yeomans, & Durlach, 2003). These results suggest the confound of an underlying motivational cue: a state of caffeine-deprivation, which would have been present only in habitual caffeine consumers. Findings from another experiment in the same laboratory (Yeomans, Durlach, & Tinley, 2005) used a within-subjects design to test

this hypothesis, using fruit teas and juices as stimuli, paired with either caffeine or placebo. Participants - all moderate caffeine consumers in this experiment - tasted and rated the CS+ and CS- for four trials each. Drinks were served at breakfast, after an overnight fast during which only water was permitted for consumption. These measures ensured participants were exposed to the drinks in a caffeine-deprived state. Rated pleasantness of the caffeine-paired drink increased significantly over the four trials, and ratings for the placebo-paired drink showed no change. The findings provide clear evidence of acquired liking for the caffeine-paired flavour (FCL). However, participants did not reliably select the caffeine-paired flavour as their 'preferred' flavour at the end of the experiment. These results combined imply acquired liking to be an unconscious process, and distinct from acquired preference.

Chambers *et al* (2007) expanded on this paradigm by ensuring that participants were trained and tested in both a caffeine-deprived state, and a non caffeine-deprived state. Fruit juices and herbal teas with novel flavours were paired with caffeine or placebo. Overall, pleasantness ratings for the caffeine-paired flavour increased, indicating FCL. The acquired liking was only statistically significant, however, when testing occurred in a caffeine-deprived state.

Hunger, an appetitive state, has also been established in several studies as a motivational cue to strengthen dietary learning. Yeomans *et al* (2006) exposed participants to odours paired with a sweet taste (sucrose), a bitter taste (quinine) or water (control). Testing occurred after an overnight fast, followed by a controlled breakfast and then a further 3-hour fast. Initial ratings were taken for each of the odours, and participants were then trained under three conditions: low-, and high-calorie preloads and a control preload. As a result, the participants were trained in a state of hunger, and tested either hungry or sated. Acquired liking for the sucrose-paired odour was expressed only when participants were hungry, after the low-calorie and placebo preloads. After the high-calorie preload, acquired liking was not evident, yet ratings of 'sweetness' for the sucrose-paired odour increased for all preload conditions, confirming that participants had formed an association between sweetness and the sucrose-paired odour. In this learning experiment the underlying association was that of FFL, rather than FCL, even though sugar (sucrose) was used to sweeten the stimuli. Participants had the opportunity to consume a maximum of 48kcal of energy during the training sessions (4 sessions x 1 sucrose-paired trial x 3 solutions x 10ml servings of 10% sucrose solution x 4kcal/g). Thus potential energy consumption during the training phase was minimal, particularly in comparison to the

preloads (high = 359kcal; low = 59kcal). Brunstrom and Fletcher (2008) exposed participants to three novel fruit teas, one of which was paired with saccharin, the other two remained unsweetened. Preference for the tea flavours was tested by a ranking exercise both pre- and post-conditioning, which included teas not used in the learning phase. All teas were presented unsweetened at testing times. Participants showed an increased preference for the sweetened tea, but only in the group that were tested hungry. The results indicate sweetness-related FFL, and provide a distinction between FFL and FCL, by the use of a non-nutritive sweet taste. In other words, learning occurred in the absence of post-consumptive consequences that could have been induced by sucrose. These findings provide further evidence of a distinction between acquired liking and acquired flavour-preference in humans, and confirm that expression of acquired liking is subject to appetitive state.

So far these studies have provided evidence for flavour-based learning under controlled conditions in the laboratory, an artificial environment very different from the circumstances in which people usually eat and drink. FFL and FCL have proven robust not only in the laboratory, but also in the context of home-consumption. For example, in Mobini, Chambers and Yeomans (2007), participants consumed peach-flavoured tea packaged in unmarked drinks cans, at home in a naturalistic setting, either before or after lunch. Testing subsequently took place in the same appetitive state experienced during training: either hungry or sated. This design differed from Yeomans *et al* (2006), where participants were trained hungry and tested either hungry or sated. Three versions of the drink were issued to participants in each of three conditions: minimally sweetened (control); with added sucrose (FCL); or with added aspartame (non-nutritive sweetener, FFL). Liking for the sucrose drink increased across both sub-groups, but significantly more so when participants were tested and trained hungry, than when tested and trained sated. FFL was evidenced by increased liking for the aspartame drink, but there was no clear difference between the appetitive states in which the training and testing took place. The contrast between results in the experimental conditions implies that the post-ingestive effects of the sucrose increased sensitivity to FCL when tested in a hunger state. The magnitude of increased liking for the sucrose drink (sated) was very similar to that of the aspartame drink (hungry and sated), which may suggest that in the absence of nutritive need, changes in liking for the sucrose (sated) group may be a response to the sweetness of the drink, rather than its energy content. To put it another way, acquired liking via FCL is enhanced when trained and tested whilst participants are motivated by hunger.

Multiple associations act to strengthen a learned preference, and learned preferences may consist of more associations than we are consciously aware of. This may explain why some associations are more resistant to extinction than others (Dwyer, 2005). Indeed, some experiments have lent weight to the argument that FFL and FCL interact to produce greater learning effects than either process alone. For example, Yeomans *et al.* (2008; Yeomans, Mobini, & Chambers, 2007).

1.3.3.2. *Learned Satiety*

The concept of Learned Satiety was first proposed by Booth (1972), and is used to label the phenomenon whereby an animal makes an association between the sensory aspects of a food stimulus (CS), and the subsequent satiating effects of the energy the food contains (US). Learned satiety is similar to flavour-consequence learning in the way that associations are acquired. However, whereas FCL is expressed as an increase or decrease in liking for the CS food, learned satiety is expressed as behavioural control exerted over consumption. In learned satiety, the associations acquired during the acquisition phase enable the animal to predict the satiating effect of the food, cued by sensory properties experienced orally and in the digestive tract. Subsequent consumption of the CS food results in cessation of feeding in anticipation of the energy content (CR). Learned satiety usually takes place after multiple exposures, complete digestion of the food is a pre-requisite in the learning phase as the effect of energy content is post-prandial.

The body of work on learned satiety may be said to originate from Le Magnen's 1956 paper (published in English, 1999), in which rats became satiated on food identical in nutritional composition, but differing in four odours with which it was paired (see Section 1.2.1.2: Sensory-Specific Satiety in Non-Human Animals for a detailed description of this study). Le Magnen suggests that under some circumstances, the cessation of feeding in rats was a response to sensory cues that they had learned to associate with energy absorption after consuming the food. In Booth's original research (1972), rats learned to adjust meal size after forming an association between an energy-dense food and a novel flavour, over multiple exposures. Similar results have been achieved with non-human primates in the same laboratory (Booth & Grinker, 1993): Bonnet monkeys adjusted meal size to compensate for conditioned association between novel-flavoured drinks paired with high-energy delivered by carbohydrates.

Evidence for control of meal size in humans (sometimes termed conditioned satiety) is more equivocal. Learned satiety as a theory assumes a predisposition to homeostatic control of feeding: consumption that is initiated and ceased on the basis of physiological cues arising from the current need for energy and nutrition. Booth was first to publish evidence of the phenomenon in humans (Booth, et al., 1976). High- or low-carbohydrate preloads were delivered as a pre-lunch drink, each signalled by a different flavour of yoghurt served as part of lunch. Repeated consumption of a low-starch preload resulted in greater consumption at lunch in comparison to the high-starch preload.

However, other researchers have been unable to replicate these results with humans. For example, after repeated exposure to flavour-cued high- and low-energy porridge, at subsequent *ad libitum* breakfasts a significantly greater portion (measured by weight) of the low-energy porridge was consumed, in comparison to the high-energy version (Yeomans, Weinberg, & James, 2005). These findings indicate learned satiety to a certain extent, but total energy intake was still greater for the high- than for the low-energy version of the porridge. In a similar study, using porridge once more, the design was augmented to include manipulations of the fixed portion size (150 or 300g) presented during training, and the presence or absence of sensory cues paired with energy-density (Yeomans, Gould, Leitch, & Mobini, 2009). In the absence of sensory cues, no differences in consumption were apparent between the high- and low-energy conditions; but when energy was cued by flavour, intake increased differentially. Repeated exposure resulted in both the high-energy small portion and the low-energy large portion increasing intake significantly at *ad libitum* testing.

It is possible that humans do not respond in the same way as rats and non-human primates because our feeding behaviours are no longer controlled primarily by homeostatic regulation: social and cultural factors play a significant part in our choices of food, meal times, and meal size. Brunstrom (Brunstrom, 2005, 2007) suggests that humans have an additional cognitive element to feeding behaviour, that variables of food choice and portion size are decided immediately in advance of the consumption phase. This would suggest that humans express learned satiety as portion control before eating - during meal-planning - whereas rats and non-human primates express control at the end of the consummatory phase, by exerting feeding-cessation. By tightly controlling experimental conditions, by removing social and cultural cues in a laboratory context and by compelling the consumption of a fixed portion over which participants have no

control, researchers face the paradox of a reduced likelihood of observing the very phenomenon we intend to measure.

1.3.4. Dietary Learning and Sensory-Specific Satiety

At the time this thesis was written, there was as yet no published evidence of experimental testing of the effects of dietary learning on sensory-specific satiety. There is arguably some evidence to suggest that high-protein foods may induce greater magnitude of SSS (see Section 1.2.2.3: Energy and Macronutrient Content), and there is abundant evidence for increase in rated pleasantness of foods for which the sensory properties have become associated with either a liked stimulus as in flavour-flavour learning, or a rewarding consequence as in flavour-consequence learning (see Section 1.3.3.1: Flavour-Based Learning). It is therefore reasonable to assume that these longer-term changes in attitude towards these foods may be reflected in an increase in the magnitude of SSS post-exposure: that hedonic changes due to dietary learning of any form, may impact the development of SSS.

1.4. Aim of the Thesis

Sensory-specific satiety is a short-term consumption-related hedonic decline. This thesis sets out to establish the extent to which SSS may be subject to modulation by long-term hedonic changes, and to characterise SSS and the experimental methods used to test for it. The aim of these experiments is to determine if the magnitude of SSS experienced for novel snack foods is subject to augmentation or attenuation as a result of repeated exposures. In Chapter 3, the first experiment assesses the effects of exposure in the absence of obvious reinforcement, by testing for the effects of mere exposure and monotony on the magnitude of SSS. Chapter 4 comprises three methodological experiments which explore the effects of number and type of contrast foods on the magnitude of SSS. Finally, in Chapter 5, two experiments examine the impact of flavour-based learning and learned satiety on the magnitude of SSS using dietary learning paradigms.

CHAPTER 2: General Methods

This thesis comprises six experiments that share several commonalities of method. For the sake of brevity, common features are detailed in this chapter, and experiment-specific detail is reported in the methods sections of the experiments in Chapters 3, 4 and 5.

The chronology of experimental data collection becomes important in the discussion of the findings in these experiments, and in understanding the rationale behind some of the experimental design and choices of food stimuli. Experiment 1 was conducted first, followed by Experiment 2. Data from Experiment 5 was collected over the course of nine months, during which Experiment 3 was performed, overlapping the end of Experiment 5 by a few weeks. Experiment 4 followed shortly thereafter, with some overlap of Experiment 6, which was implemented over the course of seven months. In terms of chronology of experimental design, the experiments were devised in the following order: 1, 2, 5, 3, 4, 6.

2.1. Methodology and Measurement of SSS in the Literature

If sensory-specific satiety is operationalised as a statistically significantly greater magnitude of decline in pleasantness for an Eaten food against sensorially-differing Uneaten food(s), the definition of sensory-specific satiety is closely connected to the way in which it is tested experimentally.

Since the first evidence of sensory-specific satiety in humans was published (B. J. Rolls, et al., 1981), subsequent SSS experiments have used similar experimental methods, hence it is possible to outline the procedural paradigm for testing sensory-specific satiety. In the pre- consumption phase, participants are presented with small quantities of a selection of food items that are sensorially different from each other, and asked to give hedonic ratings (e.g. pleasantness of the taste, texture, appearance or smell of the food; desire to eat more of the food) for each of the samples. Other ratings of experimental interest may also be taken, such as those of appetite (e.g. hunger, fullness, thirst), and taste (e.g. Sweet, salty, novel, fruity). During the consumption phase, a larger portion of one of the sample foods is presented (as the Eaten food), which may be either a fixed portion, or under *ad libitum* conditions participants may be instructed to eat as much as they want. Subsequently, in the post-consumption phase, the same selection of food samples are presented again for repeated tasting and rating.

A net 'Change In Pleasantness' score is calculated for each sampled food by deducting the pre-consumption rating from the post-consumption rating. As such, a negative score for Change In Pleasantness indicates a post-consumption decline, and a positive score indicates an increase (as seen in Hetherington, et al., 1989; Johnson & Vickers, 1992, 1993; Miller, et al., 2000; Raynor & Wing, 2006; B. J. Rolls, Hetherington, et al., 1988b; B. J. Rolls, et al., 1981; E. T. Rolls, et al., 1983; Vandewater & Vickers, 1996). In some experiments, tasting and rating has been instigated at more than one time-point after the consumption phase in order to establish the length of time for which the hedonic changes persist. In these instances, the baseline rating (from the pre-consumption phase) has been deducted from the rating given at each time-point, in order to provide further change scores (e.g. Hetherington, et al., 1989).

Change In Pleasantness scores are compared between the Eaten food and the Uneaten foods. In much of the literature, where the Change In Pleasantness score for the Eaten food is significantly lower than that of the Uneaten food(s), then sensory-specific satiety is deemed to have occurred (e.g. B. J. Rolls, 1986). In some experiments (e.g. Hetherington, et al., 1989; Johnson & Vickers, 1992; Miller, et al., 2000; Raynor & Wing, 2006; B. J. Rolls, et al., 1981; Vandewater & Vickers, 1996), hedonic change scores for the Uneaten foods have been aggregated into a single mean for statistical comparison and simplicity, which is useful when trying to simply ascertain if SSS occurred. In other situations, comparisons may be made between the Eaten food and each individual Uneaten food (e.g. B. J. Rolls, Hetherington, et al., 1988a; E. T. Rolls, et al., 1983; Vickers, Holton, & Wang, 1998). These comparisons better highlight transfer effects, where an Uneaten food (that shares some sensory characteristic with the Eaten food) may also decline in pleasantness, after consumption of the Eaten food. Such effects would not be apparent from aggregated ratings for all uneaten foods, as they would be subject to the phenomenon of regression to the mean. Vandewater and Vickers (1996) went one step further, creating a differential rating by deducting Change In Pleasantness for the Eaten food from Change In Pleasantness for the Uneaten food. Such a differential figure best serves to illustrate the magnitude of SSS in a single score, and this statistical method was used in Experiment 1 (see Section Chapter 3: Exposure Effects and Sensory-Specific Satiety).

However, when sensory-specific satiety is tested in this way, statistical assessment of SSS is not possible in the absence of ratings data from Uneaten foods, as there is nothing with which to compare the ratings of the Eaten food. This situation replicates the consumption

of a homogenous food during a meal or snack, in which SSS will manifest as a decline in pleasantness for the Eaten food without comparison to Uneaten foods. Therefore, in such instances, it makes sense to statistically assess whether the post-consumption hedonic rating for the Eaten food has declined significantly from the pre-consumption rating, regardless of the presence or absence of Uneaten foods.

It is worth noting that SSS has been measured not only using changes to pleasantness ratings, but also using changes to "desire to eat" ratings (e.g. B. J. Rolls, Hetherington, & Laster, 1988). Some studies show clear evidence of a strong relationship between pleasantness and desire to eat (e.g. Guinard & Brun, 1998; Hetherington, et al., 2000; Hetherington, et al., 2002), whilst yet others have not been able to replicate this effect (e.g. B. J. Rolls & McDermott, 1991; Smeets & Westerterp-Plantenga, 2006; Zandstra, De Graaf, Mela, & Van Staveren, 2000). Some researchers have suggested that measures of desire to eat and pleasantness tap into different states - those of 'wanting' and 'liking' respectively - which have particular definitions in the context of motivation (see Section 1.2.1.3: Critique of Sensory-Specific Satiety for a discussion on this issue). There is evidence of a dissociation between ratings for liking and wanting food, both in the animal literature (e.g. Pecina, et al., 2003) and from human studies (e.g. Berridge, 1996; Finlayson, King, & Blundell, 2008), and if such a distinction was made between measures of pleasantness and desire to eat, the disparity between them might be expected. SSS seems to represent a decline in both wanting and liking, and ratings of pleasantness may primarily be an expression of liking, but may also represent an element of wanting (again, see Section 1.2.1.3: Critique of Sensory-Specific Satiety). SSS measures such as those described above, lend themselves to parallel measures of wanting and liking, and pleasantness ratings alone are sufficient to establish the occurrence of SSS. With this in mind, the decision was taken to use pleasantness ratings throughout the experiments in this thesis.

2.2. Ethical Considerations and Procedures

All experimental protocols were approved by the University of Sussex Ethics Committee, prior to testing. Before commencing experiments, participants were given a participant information sheet related to that particular study (see Appendices C, D, E, F, G and H), which contained procedural requirements, basic participation criteria, experimenter contact details, and the total cash and/or course credits that were to be paid in recompense for completing the experiment. Written consent to the details on the information sheet was obtained, along with date of birth for the purposes of calculating age (see Appendix I for an example consent form).

In all cases, participants were told that the purpose of the study was to examine the relationship between mood and food, thus the true nature of the experiment was concealed. Such a stratagem served to direct demand characteristics away from the important experimental variables, particularly ratings of pleasantness and desire to eat more, and towards the distracter ratings of mood and flavour characteristics of the foods.

Upon completion of an experiment, participants were fully debriefed about the experimental aims, and their height and weight were recorded so that body mass index (BMI) could be calculated. Participants were paid at the rate of £5 per hour, and/or in course credits, to the value of the time they invested in participation, rounded up to the nearest fifteen minutes.

2.3. Participant Selection

All participants were recruited either by email (example recruitment email in Appendix A) or by placing flyers around the university campus. Emails were sent to subscribers of two email lists and to individuals that appear on a laboratory database maintained by the Ingestive Behaviour Unit. The first email list comprised members of the psychology-subject-pool, a list to which students and staff subscribe in order to express interest in participating in experiments run in the psychology department. For this list, once a recruitment email had passed moderation by the psychology departmental office, it was disseminated to all that subscribed to the psychology-subject-pool. The second list was for the psychology-course-credits scheme, membership of which was compulsory for taught masters students and first and second year undergraduates in psychology at Sussex. These students were required to complete at least four hours participation in psychology experiments in order to gain credits towards their research methods courses taken by each of these cohorts.

The Ingestive Behaviour Unit database contains details of previous and prospective applicants who have expressed a specific interest in participating in studies related to eating and drinking. Members of the database have completed a laboratory recruitment questionnaire (see Appendix B) which combines assessment of the restraint and disinhibition factors from the Three Factor Eating Questionnaire (TFEQ) (Stunkard & Messick, 1985) with questions related to food and drink consumption and preferences. The questionnaire allows for estimates of daily caffeine and alcohol intake, smoking status and eating-behaviour specific details such as allergies, aversions and preference for key foods used in the laboratory. The questionnaire was administered in paper format (see appendix B) and scored by hand for Experiments 1, 2, 3 and 4. For Experiments 5 and 6, the questionnaire had been implemented on a webpage[†] that was accessible via the internet. Upon completion of the online questionnaire, responses were downloaded directly into our database, and scores were automatically calculated by spreadsheet formulas. As a result of the recruitment approach, all participants were students, staff, or associates of the University of Sussex.

Recruited participants met several criteria that were imposed to maximise the chance of observing sensory-specific satiety and dietary learning. Participants were required to be

[†] <http://www.sussex.ac.uk/units/socpsy/webq/recruit/index.html>

below the age of 56 years, as sensory-specific satiety declines later in life, and may be entirely absent in the elderly (see Section 1.2.2.2: Individual Differences). All participants were aged between 18 and 52 years old, the majority being in their late teens or twenties.

Individuals were excluded if they were currently dieting, as they may have been unwilling to consume all of the fixed portion of the test snack. Those with prior diagnosis of an eating disorder were also excluded, as bulimics may not show sensory-specific satiety, and anorexics show sensory-specific satiety with much smaller portions than those without eating disorders (see Section 1.2.2.2: Individual Differences). Participants reporting or presenting with a minor illness such as cold or 'flu were asked to reschedule testing appointments once the ailment had passed. However, in one instance a participant suffered a bout of alleged food poisoning on the same day as attending the laboratory for a testing session. The participant's meal from the previous evening was later established as the cause of the illness. Nevertheless, it was possible that the illness may have caused the participant to develop an aversion to the experimental foods, or a negative association with the laboratory context. To prevent the experimental data being compromised by this event, on this occasion the participant was immediately excluded from participating.

Individuals currently taking prescribed medication (excluding oral contraceptives) were excluded, as several medications can reduce taste perception (see Section 1.2.2.1: Taste Perception Deficits). As smoking may reduce sensitivity to sweetness perception (see Section 1.2.2.1: Taste Perception Deficits), applicants who reported smoking more than five cigarettes per day were excluded from Experiments 1, 2 and 3. The smoking limit was reduced to five cigarettes per week for Experiments 4, 5 and 6, as some participants were found to be under-reporting smoking when completing the laboratory questionnaire.

In the interests of safety, individuals with diabetes or reporting allergies or aversions to any of the test foods or ingredients were excluded from participating. Gelatine was a common ingredient in test foods for all except Experiment 1, so to simplify recruitment for these experiments, vegetarians were excluded from the outset.

Experiments 5 and 6 explored the effects of flavour-based learning on the expression of SSS, so a further exclusion criterion was a score in excess of 6 on the restraint scale of the TFEQ, as there is evidence to suggest that flavour-nutrient learning and evaluative

conditioning, such as flavour-flavour learning, may be impaired in restrained eaters (see Section 1.3.3.1: Flavour-Based Learning). Eating and drinking restrictions for these two experiments required participants to abstain from caffeinated drinks from the night before testing until the afternoon of the laboratory visit. Since caffeine-withdrawal symptoms have been reported to appear within 12 hours of cessation of caffeine (Phillips-Bute & Lane, 1997), it was possible that high-caffeine consumers would experience caffeine withdrawal symptoms during this period, which may in turn have resulted in a negative association with the laboratory context. To prevent this occurrence, potential participants who self-reported consuming more than 195 mg of caffeine daily, based on the data they provided when completing the recruitment questionnaire (see Appendix B), were excluded from Experiment 5.

Studies specifically examining changes in liking for flavours dependent on their association with the presence or absence of caffeine suggest that people who are caffeine-dependent may develop a mild aversion to flavours associated with the effects of caffeine withdrawal and in a recent review, Brunstrom (2005) has argued that failing to control for caffeine consumption might therefore compromise the design of studies of other forms of flavour-based learning. Thus high caffeine consumers were excluded in Experiment 5, at the time when this concern became evident in the literature. However, subsequent research at Sussex suggested that the concerns expressed by Brunstrom (2005) were not warranted. In brief, data from two recent studies from this laboratory which examined flavour-consequence learning in the context of participants who abstained from all food and drink from 11pm the previous evening on each test or training day, were re-analysed with participants' caffeine consumption used as a covariate.

The first study (Yeomans, Gould, et al., 2008) examined changes in liking for, and intake of, a novel soup, through association with the effects of monosodium glutamate (MSG). This study followed-up a previous learning study which suggested that MSG can condition liking for a novel soup flavour (Prescott, 2004). The main finding in the new study was significant increases in the rated pleasantness of the flavour of a soup which had been associated with MSG, and increased voluntary intake of that soup post-training. Participants in that study had a wide-range of habitual caffeine intake (range 0-560 mg/day) and 10/32 participants consumed more than 195 mg/day. However, inclusion of caffeine intake as a covariate in the re-analysis of these data found no evidence that apparent effects of MSG were secondary to differences in habitual caffeine intake, and caffeine was not a significant covariate in this re-analysis.

The second recent study examined changes in liking for, and intake of, a novel flavoured sorbet as a consequence of flavour-sweetness and flavour-carbohydrate associations (Yeomans, Leitch, Gould, & Mobini, 2008). As with MSG, inclusion of habitual caffeine consumption had no effect on the outcome of that study, which was increased liking for a flavour associated with the combined effects of sweetness and carbohydrate consumption, and increased intake of the sorbet as a result of flavour-carbohydrate associations. A summary of the analysis of the data for liking change, which was most relevant to the work in this thesis, was that overall change in flavour pleasantness varied between the five training conditions in that study, and that although estimated daily caffeine intake data were only available for 41/64 participants, the effect of condition was still statistically significant with this smaller sample, while caffeine again was not a significant covariate. The use of a habitual caffeine intake of less than 195mg/day as an inclusion criterion in Experiment 5 greatly restricted the range of potential participants. Limiting participant selection in this way for Experiment 6 could not be justified by re-analysis of recent data from learning studies, which demonstrated caffeine consumption to be unlikely to confound similar experiments. Consequently the caffeine intake criterion was dropped for Experiment 6 participant recruitment.

Participants were not screened for body mass index (BMI), as evidence suggests that BMI does not modulate sensory-specific satiety (see Section 1.2.2.2: Individual Differences) or learning (see Section 1.3.3: Dietary Learning), and excluding participants on the basis of body weight may be ethically sensitive. As evidence suggests both males and females exhibit similar responses to sensory-specific satiety (see Section 1.2.2.2: Individual Differences) and dietary learning (see Section 1.3.3: Dietary Learning), gender was considered only as a logistical factor during participant recruitment. Women are heavily prevalent in the database and email lists, outnumbering men by a ratio of 3:1. Experiments 2, 3 and 4 required participants to attend the laboratory on a single day and therefore included women only, as this enabled fast recruitment over short time scales. The multiple sessions of Experiments 1, 5 and 6 resulted in much longer testing durations, that enabled more time to recruit male participants, so these experiments included an equal number of males and females.

In order to reduce expectancy effects and conserve naivety of experimental aims, participants were excluded if they had taken part in any similar studies in this laboratory. Individuals' details of participation in previous experiments are kept centrally on the laboratory database, and updated regularly. Upon completion of an experiment,

participants were excluded from taking part in further experiments that contributed to this thesis. However, participants were permitted to take part in pilot tests for future experiments, as these required only hedonic and sensory assessment of stimuli on a single occasion. In order to gain true novelty ratings upon first exposure to test foods in experiments, all individuals who took part in a pilot test were excluded from participating in the subsequent related experiment.

2.4. Apparatus and Materials

2.4.1. Laboratory Setup

All breakfast, testing and exposure sessions took place in the laboratory of the Ingestive Behaviour Unit at the University of Sussex. Air conditioning ensured a constant ambient temperature of 21°C throughout the laboratory, including the waiting room, testing cubicles and booths. All testing for sensory-specific satiety took place in individual windowless cubicles, each equipped with an Apple Macintosh G3 computer (both the Power Macintosh and the iMac models were used) running the OS9.1 version of Apple's operating system.

Unipolar visual analogue scales (VAS) were used throughout the experiments in this thesis. A VAS is a linear representation of a two-dimensional scale, anchored at the ends with either unipolar (e.g. 'very hot – not at all hot') or bipolar (e.g. 'very hot – very cold') indicators. Participants mark the scale at the most appropriate place, to express their response to the stimulus. The measurement of SSS relies entirely on ratings data, and SSS experiments predominantly use VAS (e.g. Hetherington, 1996; Hetherington, et al., 1989; E. T. Rolls, et al., 1983; E. T. Rolls & Rolls, 1997; Weenen, et al., 2005) to elicit hedonic response data, rather than, for example, a magnitude estimation scale, which is less intuitive and requires practice. Magnitude estimation scales require the participant to imagine, at one polarity, the complete absence of the characteristic being measured, and at the other, the strongest possible imaginable magnitude of the same stimulus. In order to be consistent with the broader literature on SSS, and in line with methodology previously used in a doctoral thesis on SSS at the University of Sussex (Atton, 2006), unipolar VAS were selected as the most appropriate method of assessing participant ratings in all the experiments.

Sussex Ingestion Pattern Monitoring (SIPM) software was used to administer the SSS test questions and record participants' responses. The SIPM program is designed for human ingestive behaviour experiments, and is based on the Universal Eating Monitor (Kissileff, Klingsberg, & Van Itallie, 1980). Mood and appetite questions were presented as: "How [word] do you feel?" where [word] was the relevant adjective. Hedonic and sensory questions were presented as: "Rate the following property of that food: [x]", where [x] indicated the relevant attribute.

All questions were presented as sequential VAS. The text of each question appeared centrally above a horizontal bar anchored at one end with "not at all" in black and at the other with "extremely" in red. When each question appears on the screen, a vertical bar crosses the horizontal scale in the centre, and participants use the mouse to move the bar, thus indicating their rating. Once a rating has been completed, participants must click an on-screen button labelled 'Done' in order to move on to the next rating.

Unknown to the participants, each scale has 500 segments, and thus responses could be any integer from zero to 500. The SIPM program is set up to randomise the order in which food samples are tasted (where there is more than one), the presentation order of questions within each evaluation phase, and the polarity of the VAS response anchors. Randomisation prevents boredom and balances any order effects, and sequential presentation of the scales prevents participants from referring back to previous responses. Response data for each test session are recorded chronologically in a single text file.

In all experiments, appetite ratings of 'hungry', 'full' and 'thirsty' were used, along with sensory and hedonic ratings of 'pleasant', 'novel', 'sweet', 'sour', and 'bitter'. Additional ratings were included in specific experiments: 'fruity' in Experiment 1; 'savory' in all except Experiment 1; and 'your desire to eat more of this' in Experiments 5 and 6. Mood ratings, which served only as distracters, varied between experiments, but always numbered four.

2.4.2. Laboratory Breakfasts

Experiments 1, 2, 5 and 6 included the provision of controlled breakfasts served in the laboratory waiting room: either two hours before testing (in Experiments 1 and 2), or three hours before testing and exposure sessions (in Experiments 5 and 6). Breakfasts were served between 07:30h and 10:00h, the exact times varied between and within experiments and participants. In all of these studies breakfast consisted of 60g of breakfast cereal served in a 300 ml white ceramic bowl, with 160g semi-skimmed milk, and 200g orange juice served in separate glasses. In Experiments 1, 2, 3 and 4, the breakfast cereal was Kellogg's Crunchy Nut Cornflakes for all participants. For Experiments 5 and 6, participants selected either Kellogg's Crunchy Nut Cornflakes, or Kellogg's Special K at the start of the experiment, and received the same cereal for the duration of the experiment. Both breakfasts were similar in macronutrient and energy content (shown in Table 2.1).

Table 2.1: Macronutrient and Energy content of the laboratory breakfasts

	Crunchy Nut breakfast				Special K breakfast			
	Kcal	Protein	CHO	Fat	Kcal	Protein	CHO	Fat
Cereal	238.2	3.6	49.3	3.0	240.0	4.8	43.8	5.4
Milk	78.4	5.4	8.0	2.7	78.4	5.4	8.0	2.7
OJ	94.0	1.0	21.0	0.0	94.0	1.0	21.0	0.0
Total	410.6	10.0	78.2	5.7	412.4	11.2	72.8	8.1

2.5. General Procedure

All testing for sensory-specific satiety was administered and recorded by SIPM software (see Section 2.4.1: Laboratory Setup). When running parameters for SSS testing, the SIPM program prompts the participant to call the experimenter on three occasions.

Consequently, and in line with the accepted SSS testing paradigm (see Section 2.1: Methodology and Measurement of SSS in the Literature), the SSS testing session is divided into four phases.

In the first phase, participants completed measurements of mood and appetite. In the second phase (pre-consumption), the experimenter provided samples (3-5 g) of the test snack and relevant contrasting snacks in clear plastic 50ml containers, each labelled with a letter and presented in alphabetical order on a white plastic tray (28.3 x 21.4 cm). For each test food sample, sensory and hedonic ratings were preceded by the statement: "The food is: Snack [Y]" where Y is the relevant label of the food. Specific instructions for tasting the food followed: "Eat a sample of the food now, sufficient for you to decide how it tastes. It is important that you do not eat any more during the questions that follow". Participants gave sensory and hedonic evaluations for each sample, then appetite ratings were repeated.

In the third phase (consumption), the tray of samples was replaced with a tray containing a 50 g portion of the test snack, and a paper napkin. The test snack was presented in either a clear plastic 120 ml container (Experiments 5 and 6), or a 300 ml white ceramic dish (Experiments 1, 2, 3 and 4), whichever was most suitable for the volume and type of test food presented. The SIPM software instructed participants to "Please eat all of the snack portion".

Whilst SSS experiments have used both fixed and *ad libitum* portions (see Section 2.1: Methodology and Measurement of SSS in the Literature), fixed portions were used in the consumption phase of these experiments for three main reasons. Firstly, controlling for portion size during the consumption phase provided consistency within and between participants and experiments, and removed volume of intake as a possible confounding variable. This was especially important in Experiments 1, 5 and 6, where identical SSS tests were repeated during the course of the experiment, and compared with one another in the analyses. Secondly, SSS is related to the sensory aspects of the food (see Section 1.2.1.1: Sensory-Specific Satiety in Humans), not energy content (See Section 1.2.2.3:

Energy and Macronutrient Content), and measurement of decline in pleasantness should be unaffected by a fixed portion as opposed to *ad libitum*. Therefore, the Eaten food portion size need only be sufficient to induce a decline in pleasantness significantly greater than the Uneaten food(s): consumption of the Eaten food to satiety should be unnecessary. There is evidence that larger portions increase the magnitude of SSS (See Section 1.2.2.3: Energy and Macronutrient Content). If some participants were to consume larger portions, this would allow for the possibility of general or physiological satiety to occur, and the time taken to consume such portions would make it difficult to eliminate post-ingestive factors as contributing to pleasantness decline. Thirdly, a fixed portion emulates a snacking session (rather than a meal situation) more readily than an *ad libitum* portion: the types of snack foods used in these experiments are typically packaged and distributed in fixed portions. In the consumption phase of these experiments, the Eaten food portion was limited to 50 g. Previous research in this laboratory assessed the effect of various portion sizes during the consumption phase of SSS, and findings showed that 50g (approximately eight squares of Cadbury's Dairy Milk) was sufficient to induce optimum sensory-specific satiety (Atton, 2006).

In the fourth and final phase (post-consumption), the tray was replaced with a second series of samples the same as the first, and appetite ratings were again taken. Where necessary, a spoon was provided on each tray throughout testing. Participants repeated sensory and hedonic evaluations of the sample snacks, followed by repeated mood and appetite evaluations.

The procedure for Experiments 2, 3 and 4 involved evaluating up to five snacks, both before and after consumption of the SSS portion. To minimise the possibility of sensory and hedonic ratings being confounded by thirst, a bottle of water and a fresh glass were provided in each cubicle for these experiments. At the start of the test sessions for these experiments, participants were verbally instructed to "Please help yourself to water at any time during the session, as I don't want thirst to interfere with your ratings".

2.6. Data Analysis

All quantitative data were analysed with SPSS software, version 16 for Mac OSX. All means are presented with standard errors (Mean \pm 1 SEM), in both text and figures. Statistical significance is determined with an alpha value of .05, and the Bonferroni method of correction was used to control for Type 1 errors when conducting Analysis of Variance (ANOVA). In line with APA style guidelines, exact probability statistics are presented, as calculated to three decimal places of precision, except where the p-value is particularly small (e.g., $p < .001$).

Thirst and Mood ratings served only as distracters, and as such were not analysed. Sensory ratings were analysed where they related to an *a priori* assumption of the experimental foods. Baseline pleasantness and novelty ratings were analysed in all experiments to check for floor- or ceiling-effects.

To facilitate the analysis of sensory-specific satiety, and in line with the accepted methods in the literature (see Section 2.1: Methodology and Measurement of SSS in the Literature), a new variable 'Change In Pleasantness' was calculated for each food in SSS tests by deducting the post-consumption pleasantness rating from the pre-consumption pleasantness rating for that food. This procedure was replicated with the 'Desire to eat more' ratings, where used, to create a new variable 'Change In Desire To Eat'. In both instances, negative valence of the 'change in...' variable indicated a decline, and a positive valence an increase, in the relevant hedonic rating, post-consumption.

There are several statistical methods for assessing SSS (see Section 2.1: Methodology and Measurement of SSS in the Literature), and the methods of data collection in these experiments allowed for all possible analyses.

CHAPTER 3: Exposure Effects and Sensory-Specific Satiety

3.1. Experiment 1

3.1.1. Exp. 1 Background

The overall aim of the single study reported in this chapter was to examine for the first time whether mere exposure or monotony will develop as a result of repeated exposure to a novel food, and whether these phenomena affect the extent to which sensory-specific satiety develops in a snack context. Experiment 1 was planned and conducted first, because the findings would have implications for the design of further experiments to explore the consequences of dietary learning on SSS. By its nature, dietary learning requires exposure to food stimuli, so it was important first to establish the extent of the influence of repeated exposure or monotony alone on SSS, without deliberately manipulating a conditioned association with another stimulus.

Mere exposure (described and discussed in Section 1.3.1.1: Mere Exposure), a phenomenon observed by Zajonc (1968), refers to elevated positive attitude towards a stimulus, as a direct outcome of repeated exposure to the stimulus. The increase in liking is borne of familiarity, and Zajonc defined mere exposure as occurring in the absence of conditioning: during the course of exposure, the stimulus becomes associated with neither positive reinforcement nor negative consequence. When we eat, we rarely do so in a situation that is free of any context, so there is always potential for forming casual associations between food stimuli and the context in which they are consumed (e.g. Mela, 2001). Thus, in theory mere exposure happens without learning, though in practice it is impossible to ensure that arbitrary learning does not transpire as a result of the very encounters with the stimulus that give rise to mere exposure.

The relationship between exposure to, and heightened liking for a stimulus would seem to be monotonic at the lower end of the scale: for example, with fewer than twenty exposures. Such a monotonic relationship between liking and exposure to food stimuli has been recorded in a number of studies (e.g. (Crandall, 1985; Pliner, 1982; Stevenson & Yeomans, 1995)). Zajonc (1968) however, observed a log-linear relationship between liking and exposure: greater magnitude of increased liking with fewer exposures, with diminishing returns as the frequency of exposures increased. The difference between the monotonic and log-linear patterns observed may be a result of the novelty or familiarity

of the stimulus: the studies by Pliner(1982); Crandall(1985); and Stevenson & Yeomans (1995) all used novel stimuli. If this is the case, the flattened upper part of the log-linear curve may indicate (over) familiarity - a plateau in effect - and may serve to explain why foods that are familiar are less susceptible to the mere exposure effect. Mere exposure is greater for novel, or close to novel stimuli, than for stimuli with which we are already familiar and where the effect may even go unnoticed (Pliner, 1982; Zajonc, 1968).

Monotony is signalled by a post-exposure decrease in positive attitude towards the exposure stimulus, where exposure occurs in the absence of obvious reinforcement. Decline in liking due to monotony does not manifest uniformly across foods (see Section 1.3.1.2: Monotony). Some, for example bread and butter, gravy, and chips, appear resistant to monotony (Hetherington, et al., 2000; Hetherington, et al., 2002; Johnson & Vickers, 1992; Meiselman, et al., 2000). Unlike SSS, which reliably predicts subsequent food consumption, monotony appears to reduce reported pleasantness but not subsequent intake (Hetherington, et al., 2002). Variety is another factor that may contributory to inconsistent monotony effects: When access to other foods is denied, a single, nutritionally complete food can be consumed for several days without significant decline in rated pleasantness (Pelchat & Schaefer, 2000). As with mere exposure, it is possible that arbitrary associations may be formed during the course of exposure to a food stimuli, and therefore monotony cannot be guaranteed to occur entirely independently of dietary learning. If spurious negative associations are formed with the food stimulus, a decline in pleasantness ratings may result.

Sensory-specific satiety, as a decline in rated pleasantness of an eaten food, occurs during a single episode of consumption and persists for only a little while afterwards (Hetherington, et al., 2002). Mere exposure and monotony on the other hand, occur usually as a result of repeated or prolonged exposure (see Section 1.3.1: Mere Exposure and Monotony). All three phenomena exert an influence on perceived pleasantness of the stimulus food, either increasing (mere exposure), or decreasing pre-exposure pleasantness ratings (monotony, SSS).

A pre-requisite of dietary learning is exposure: and a resulting learned association between the food stimulus and another stimulus or consequence (see Section 1.3.3: Dietary Learning). The long-term aims of the research for this thesis were to establish if dietary learning impacted on the magnitude of SSS. Thus, in preparation for later learning studies (see Experiment 5 and Experiment 6), Experiment 1 was designed to determine

whether mere exposure or monotony, in the absence of experimentally-manipulated reinforcement, would modulate the magnitude of pleasantness decline associated with SSS. As discussed, ensuring the absence of spurious learning is impossible, but steps were taken to mitigate the possibility of, and to minimise the impact of any learned associations attached to the exposure foods.

The present study examined the effect of a thirteen-consecutive-day home-consumption exposure to a novel snack food on ratings of pleasantness and novelty, and on the magnitude of SSS. Novelty ratings for the exposure snack were predicted to decrease, regardless of experimental condition. Post-exposure, any observed increase to baseline pleasantness ratings were predicted to indicate a mere exposure effect; and any observed decline to indicate a monotony effect. The main focus of this experiment was on how SSS was modulated by repeated exposure, both as a consequence of possible changes in initial liking and as a consequence of greater familiarity with the characteristics of the ingested food. To date, these effects have not been tested on novel foods, only on common foods already familiar to the participants (see Section 1.3.1: Mere Exposure and Monotony). Exposures were conducted outside of the contrived laboratory setting in order to minimise the possibility of dietary learning. Additionally, participants selected the time of day, and context in which they consumed the exposure snacks - again, to minimise the possibility of forming arbitrary learned associations during exposure.

3.1.2. Exp. 1 Method

3.1.2.1. Exp. 1 Design

The experiment used a mixed design, contrasting changes in novelty and pleasantness ratings of two sweet snack foods (Eaten and Uneaten), before and after a two-week exposure to one of the experimental foods (within subject), between four conditions. Conditions were based on the snack consumed in the Exposure phase between the SSS test days, as presented in Table 3.1.

Table 3.1: Attribution of experimental conditions for Experiment 1

Condition	Food consumed in exposure phase
Eaten-exposure	Eaten food in SSS tests
Uneaten-exposure	Uneaten food in SSS tests
Placebo-exposure	Savoury snack not used in SSS tests
Control	none

3.1.2.2. Exp. 1 Participants

Inclusion and exclusion criteria for recruitment are detailed in Section 2.3: Participant Selection. Thirty-two men and thirty-two women were recruited and randomly assigned to one of four exposure snack conditions, giving sixteen participants in each condition (8 men and 8 women). Data from two participants were ultimately excluded from the analyses, as the individuals had failed to comply with the home-consumption requirements during the Exposure phase of the experiment. The remaining sample of 62 participants' ages ranged from 19 to 51 years old (mean 24.1 ± 0.7) and BMI ranged from 17.9 to 35.0 kg/m² (mean 23.0 ± 0.4). Neither age ($F(3, 58)=1.74$, $p=.170$) nor BMI ($F(3, 58)=0.50$, $p=.684$) differed significantly between the four conditions.

3.1.2.3. Exp. 1 Foods

Seven chocolate bars and nine cereal bars were piloted with the aim of selecting two test snacks that were similar in energy-density yet sensorially different, in order to maximise the chances of observing SSS. Eight women and eight men were presented with samples (3 - 5 g) of each snack in individual 50 ml clear plastic containers labelled with a letter and ordered alphabetically on a tray. Sensory and hedonic evaluations of each food were

completed using electronic VAS administered by SIPM software (see Section 2.4.1: Laboratory Setup). Participants rated each sample on the following properties: bitter; sour; sweet; novel; and pleasant.

The aim of the pilot study was to identify a chocolate bar and a cereal bar that were rated moderately pleasant (in order to minimise ceiling and floor effects), and rated with some degree of novelty (to ensure prior learning did not interfere with pleasantness ratings). A single-sample t-test was conducted on pleasantness ratings for each snack bar, with 250 as the test value, as this was the mid-point of the possible ratings range of 0 to 500. Snack bars with pleasantness ratings significantly different from the test statistic of 250 were excluded as test food candidates for the experiment, as the pleasantness ratings were too polarised to be considered moderate. Novelty ratings were not statistically tested, as any rating above zero implies that the snack bar was novel in some way. Results are shown in Table 3.2

Table 3.2: Mean pleasantness and novelty ratings for each snack bar tested in the pilot study for Experiment 1. Snack bars in bold type were selected for inclusion in the main Experiment.

	Pleasantness rating (/500)	Novelty rating (/500)
Chocolate Bars		
Geranium & orange dark chocolate (Montezumas)	224.4 (± 48.2)	258.3 (± 43.2)
Nutmeg milk chocolate (Montezumas)	233.1 (± 42.6)	367.7 (± 27.5)
Sweet paprika & strawberry milk chocolate (Montezumas)	325.8 (± 34.0)*	204.6 (± 38.8)
Cinnamon white chocolate (Montezumas)	287.8 (± 39.3)	326.0 (± 39.2)
Peppermint & vanilla milk chocolate (Montezumas)	242.2 (± 39.9)	287.3 (± 36.4)
Cocoa Via chocolate almond (Mars Inc)	217.5 (± 56.8)	370.7 (± 36.0)
Coccoa Via chocolate blueberry (Mars Inc)	245.7 (± 58.0)	314.2 (± 47.0)
Cereal Bars		
Maple & pecan (Jordans)	230.1 (± 31.8)	199.8 (± 36.7)
Papaya, pineapple & milk chocolate (Alpen)	358.3 (± 34.0)*	351.9 (± 33.9)
Orchard fruits & yoghurt (Sainsbury's)	336.8 (± 34.2)*	257.1 (± 33.6)
Cranberry & yoghurt (Sainsbury's)	344.7 (± 33.6)*	264.3 (± 30.7)
Be Good To Yourself pink grapefruit (Sainsbury's)	227.4 (± 40.2)	356.7 (± 21.1)
Nutrigrain blueberry (Kellogg's)	384.1 (± 31.6)*	236.1 (± 34.9)
Special K peach & apricot (Kellogg's)	278.1 (± 33.6)	374.5 (± 22.2)
Special K apple & pear (Kellogg's)	294.8 (± 41.3)	300.1 (± 33.2)
Fruitasia strawberry (Mars Inc)	251.9 (± 40.2)	340.2 (± 36.2)

* Indicates a pleasantness rating significantly different to the test value of 250 ($p < .05$).

In this pilot study, one product (the "Be Good To Yourself" pink grapefruit bar, Sainsbury's plc.) produced a pattern of results for pleasantness and novelty which best fitted the study requirements, but soon after the pilot tests were completed, the manufacturer ceased production of this product. The "Fruitasia strawberry" bar was then selected as a substitute, since it was neutral in pleasantness and highly novel, however this product was still in prototype form and subsequently the manufacturer (Mars Inc) decided not to go ahead with mass production of the bar. Consequently, the two remaining products which came closest to the study requirements ("Special K" peach & apricot cereal bar (Kellogg's, UK) and the "Cocoa Via" almond chocolate bar (Mars Inc, USA) were selected as the test foods.

A third, savoury snack of similar energy density was selected without piloting, to serve solely as the exposure snack for the Savoury exposure condition: ready salted "potato triangles" (Sainsbury's, UK). Energy and macronutrient content of the three snack foods used in testing are shown in Table 3.3.

Table 3.3: Macronutrient and energy composition of the foods included in Experiment 1.

	Per 100 g			Per 50 g portion		
	Chocolate bar	Cereal bar	Potato snack	Chocolate bar	Cereal bar	Potato snack
CHO (g)	59.1	73.0	62.4	29.5	36.5	31.2
Protein (g)	4.5	8.0	9.8	2.3	4.0	4.9
Fat (g)	9.1	8.0	13.9	4.5	4.0	7.0
Energy (kcal)	364.0	400.0	414.0	182.0	200.0	207.0

3.1.2.4. Exp. 1 Rating Scales

During both SSS tests, all ratings were taken using electronic VAS with SIPM software (see Section 2.4.1: Laboratory Setup). Ratings were taken for appetite ('hungry', 'full' and 'thirsty'), hedonics ('pleasant') and sensory attributes ('novel', 'sweet', 'sour', 'fruity', and 'bitter') of the foods. Mood ratings were taken ('sad', 'calm', 'cheerful' and 'angry'), but as these served only as distractors, these ratings were not analysed.

3.1.2.5. Exp. 1 Procedure

Each participant attended the laboratory on two separate days for SSS testing. Experimental days were separated by thirteen non-experimental days constituting an Exposure phase, during which they consumed snacks issued for home-consumption by the experimenter. Participants fasted from 23:00h on the night before laboratory sessions, consuming nothing but water until arrival at the laboratory, at which point the controlled breakfast was provided (see Section 2.4.2: Laboratory Breakfasts). After breakfast, participants were free to leave the laboratory, but continued fasting (water was allowed) until they returned for testing, which took place two hours after the breakfast appointment, in a snack context.

Mood, appetite, sensory and hedonic ratings were completed by electronic VAS administered by SIPM software (see Section 2.4.1: Laboratory Setup), and testing was carried out in accordance with the standard SSS testing procedure (see Section 2.5: General Procedure). Samples of two test foods were presented in the pre-consumption and post-consumption phases of SSS testing: the chocolate bar (always presented as Food A) and the cereal bar (always presented as Food B). During the consumption phase of SSS testing, 50g (see Section 2.5: General Procedure) of either the chocolate or the cereal bar were presented (as the Eaten food), and this allocation was counterbalanced in all experimental conditions. All test foods were presented at room temperature in all SSS tests.

Immediately after the first SSS test session, participants in the three exposure conditions were provided with thirteen 50g portions of the relevant snack food in unmarked, plastic resealable food bags. Participants were instructed to eat one portion a day, starting the following day, to eat the whole portion in one sitting, and to record the time of day they consumed the snack on a form given to them by the experimenter. This part of the procedure was designed to encourage compliance to consumption instructions. Participants in the Control condition were not issued with snacks, and were unable to observe other participants receiving theirs.

Participants' exposure food was dictated by the exposure condition to which they were allocated: the Eaten exposure group received the same snack bar they had consumed during the consumption phase of SSS testing, the Uneaten exposure group received the snack bar they rated, but did not consume during the consumption phase of SSS testing,

and the Placebo exposure group received the salted potato snack which was not presented during SSS testing.

All participants returned to repeat the SSS testing procedure with the same foods, fourteen days later. At the end of the second test session, participants completed a verbal structured debrief, of which the experimenter made notes (see Appendix J for the experimenter form). Firstly, participants were asked "What do you think the study was about?", followed by "Do you have any problems or concerns about the study?". Finally, participants were asked "Are there any further comments you would like to make?".

3.1.3. Exp. 1 Results

3.1.3.1. Exp. 1 Initial Pleasantness and Novelty Ratings

The two exposure foods used in this experiment were selected from the pilot study based on two pre-requisites: that each would be rated fairly novel and moderately pleasant. Initial pleasantness and novelty ratings were assessed to check the foods used met these assumptions.

Initial Pleasantness Ratings

As there were no treatment differences between experimental groups pre-exposure, any spurious differences in pleasantness ratings on initial contact with the test foods may interfere with later analysis of changes to pleasantness ratings post-exposure. To check for such group differences, initial pleasantness ratings from test day 1 were analysed with a mixed ANOVA, with food (Eaten, Uneaten) as the within-subject factor, and condition (Eaten exposure, Uneaten exposure, Placebo exposure, Control) as the between-subject factor (data are shown in Figure 3.1). Initial pleasantness ratings did not significantly differ between exposure conditions (main effect of condition $F(3, 58)=0.22$, $p=.883$) or between test foods (main effect of food $F(1, 58)=0.73$, $p=.397$), and the interaction effect was non-significant (food x condition interaction $F(3, 58)=0.07$, $p=.974$). Such results indicate that at baseline, pleasantness ratings were similar for both test foods across all four exposure conditions, as expected. One-sample t-tests of pleasantness of both the Eaten and Uneaten foods against a value of 250, which represents the midway point on the ratings scale of 0 to 500 showed that both the Eaten food (mean = 346.5 ± 13.7 , $t(61)=7.04$, $p<.001$) and the Uneaten food (mean = 364.5 ± 15.3 , $t(61)=7.49$, $p<.001$) were significantly more pleasant than neutral, but the mean pleasantness ratings suggested that average liking was sufficiently below the 500pt rating level to prevent ceiling effects in liking obscuring the study outcome.

Although the snack bars were counterbalanced within each experimental condition, ratings for pleasantness were also tested for each snack (chocolate bar, cereal bar) to ensure that there they were not dissimilar for such ratings. Initial pleasantness ratings of the chocolate bar and the cereal bar taken during the pre-consumption phase of SSS testing on experimental day one were compared in a one-sample t-test against a value of 250, which represents the midway point on the ratings scale of 0 to 500. Mean

pleasantness ratings for both the chocolate bar (mean = 336.1 ± 15.8 , $t(61)=5.46$, $p<.001$) and the cereal bar (mean = 374.8 ± 12.7 , $t(61)=9.80$, $p<.001$) were higher than, and differed significantly from, the midway point (250), indicating that the snacks were moderately liked.

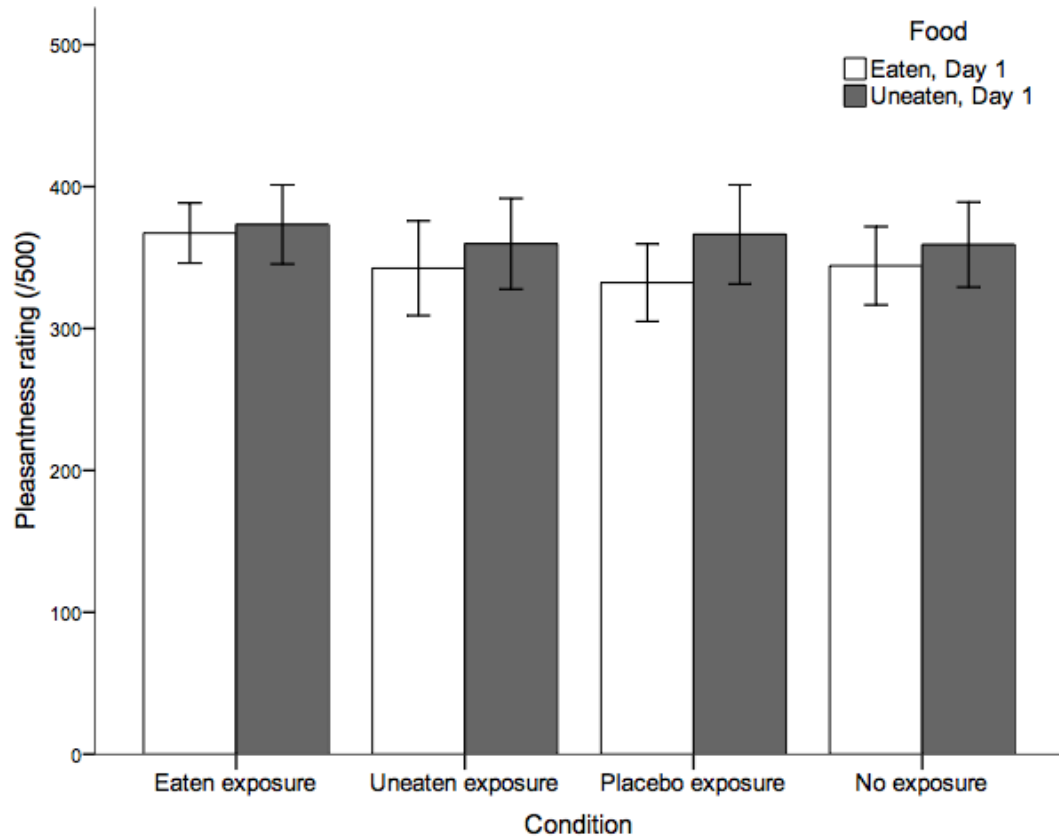


Figure 3.1: Initial pleasantness ratings for each food at pre-exposure (test day 1) for Experiment 1.

Initial Novelty Ratings

As with pleasantness ratings, any spurious differences in novelty ratings on initial contact with the test foods may interfere with later analysis of changes to novelty ratings post-exposure. To check for such group differences, initial novelty ratings from test day 1 were analysed with a mixed ANOVA, with food (Eaten, Uneaten) as the within-subject factor, and condition (Eaten exposure, Uneaten exposure, Placebo exposure, Control) as the between-subject factor (data are shown in Figure 3.2). Initial novelty ratings did not significantly differ between exposure conditions (main effect of condition $F(3, 58)=2.04$, $p=.118$) or between test foods (main effect of food $F(1, 58)=2.42$, $p=.125$), and the interaction effect was non-significant (food x condition interaction $F(3, 58)=1.09$, $p=.362$). Such results indicate that at baseline, novelty ratings were similar for both test

foods across all four exposure conditions, as expected. Figure 3.2 does suggest some minor differences in novelty between treatment conditions, however, and although the foods were clearly unfamiliar (none of the novelty ratings were close to zero), neither food was rated as highly novel either.

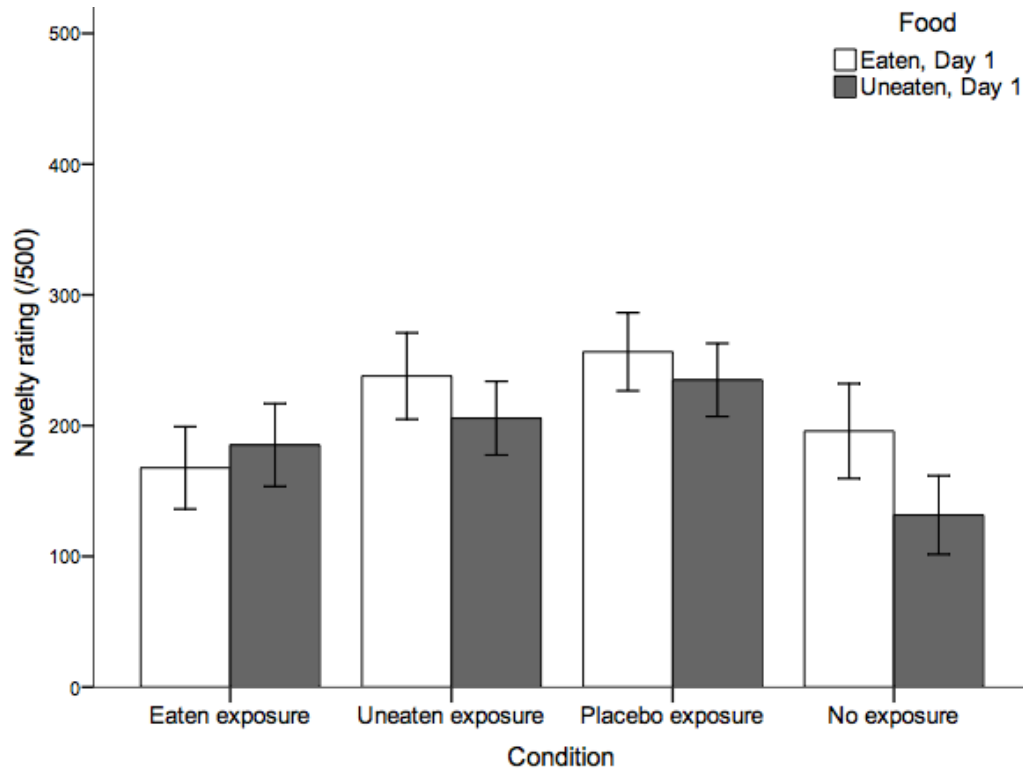


Figure 3.2: Initial novelty ratings for each food at pre-exposure (test day 1) for Experiment 1.

3.1.3.2. Exp. 1 Changes in Initial Novelty Ratings for the Exposure Food Over the Course of Exposure

A basic premise of the experiment was that participants in two exposure conditions (Eaten exposure and Uneaten exposure) would find the food they consumed repeatedly at home more familiar post-exposure (test day 2) than on the first experimental day, which would be reflected in a decline in novelty scores for the exposure food across test days. Novelty scores were expected to change little, if at all, in the Placebo exposure and No exposure conditions. To test this premise, novelty ratings taken in the pre-consumption phase of each SSS testing session were analysed with a separate repeated measures ANOVA for each exposure condition, with test food (Eaten, Uneaten) and each SSS test session (Day 1, Day 2) as the within-subject factors. Novelty ratings data are shown in Figure 3.3.

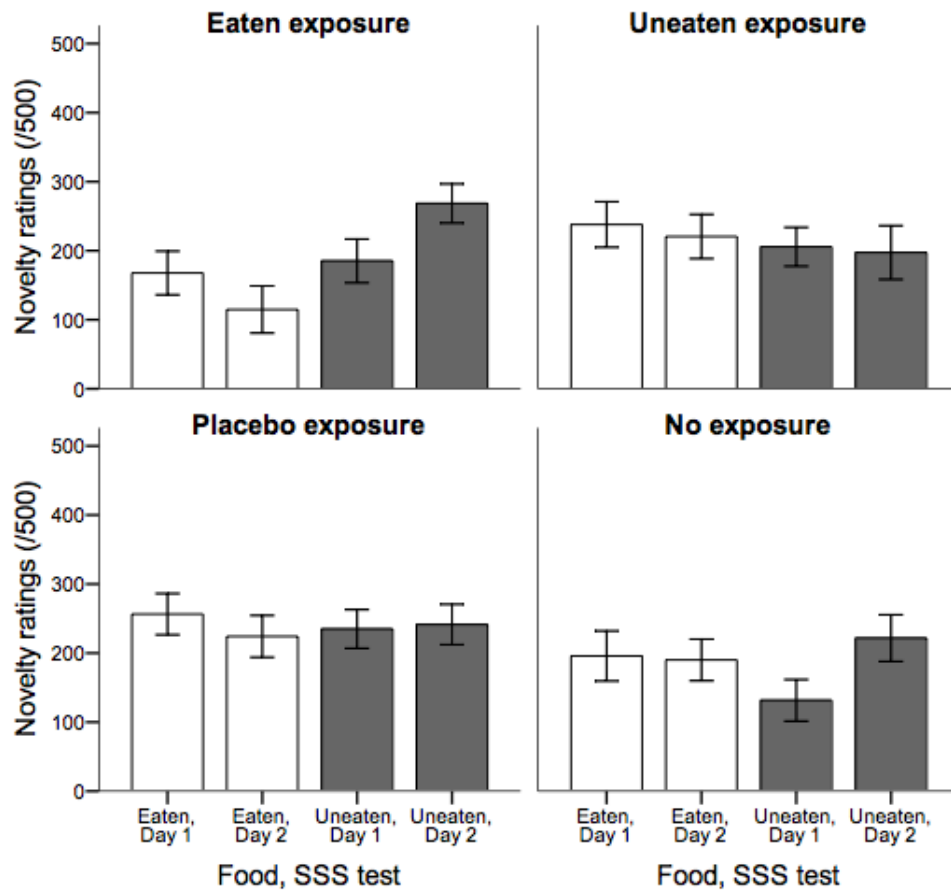


Figure 3.3: Novelty ratings for each food during pre-consumption phase of each SSS test for Experiment 1.

Eaten Exposure Condition

It was expected that the Eaten exposure condition would rate the Eaten food as less novel post-exposure, and this was supported. There was a significant main effect of food ($F(1, 14)=9.22, p=.009$), but not of test day ($F(1, 14)=0.48, p=.498$), and a significant interaction between food and test day ($F(1, 14)=5.23, p=.038$). These results indicate that novelty ratings for this group differed between conditions differently across test days, with the Eaten food declining in novelty across time whilst the Uneaten food increased in novelty.

Uneaten Exposure Condition

For the Uneaten exposure condition, it was expected that novelty ratings for the exposure food (Uneaten food) would decline post-exposure. Both the Eaten and Uneaten foods declined in novelty ratings between test days, though this trend was not statistically significant. Both main effects of food ($F(1, 15)=0.91, p=.357$) and test day ($F(1, 15)=0.23,$

$p=.640$) were not significant, nor was the interaction between food and test day ($F(1, 15)=0.03$, $p=.869$). These results suggest that although there was a little decline in novelty ratings for both test foods, such decline was not significant across the test days.

Placebo Exposure Condition

Little, if any change in novelty ratings was expected to occur over test days for the Placebo exposure group. This assumption was statistically supported with non-significant main effects of food ($F(1, 14)=0.12$, $p=.915$), test day ($F(1, 14)=0.24$, $p=.633$), and the interaction between food and test day ($F(1, 14)=1.81$, $p=.200$). These results suggest that the exposure phase had no significant effect on novelty ratings for the Eaten and Uneaten test foods.

Control Condition

Novelty ratings for the control conditions were expected to be unaltered by the exposure phase, which was supported by non-significant results for the main effects of food ($F(1, 15)=0.80$, $p=.386$), test day ($F(1, 15)=2.43$, $p=.140$), and the interaction between food and test day ($F(1, 15)=3.04$, $p=.102$). These results suggest that the exposure phase had no significant effect on novelty ratings for the Eaten and Uneaten test foods.

3.1.3.3. Exp. 1 Mere Exposure and Monotony

It was expected that participants in the Eaten and Uneaten exposure conditions may experience an effect of either mere exposure or monotony, and that this experience would be reflected respectively in either an increase or decline to pleasantness ratings of the exposure food, post exposure. As neither the Placebo exposure group nor the Control group were expected to experience these phenomena, no such change to pleasantness ratings for either test food were predicted for these conditions. To test these hypotheses, a separate repeated measures ANOVA was conducted on pleasantness ratings in the pre-exposure phase of SSS testing, for each exposure conditions. Test food (Eaten, Uneaten) and test day (Day 1, Day2) were the between-subject factors. Pleasantness data are shown in Figure 3.4.

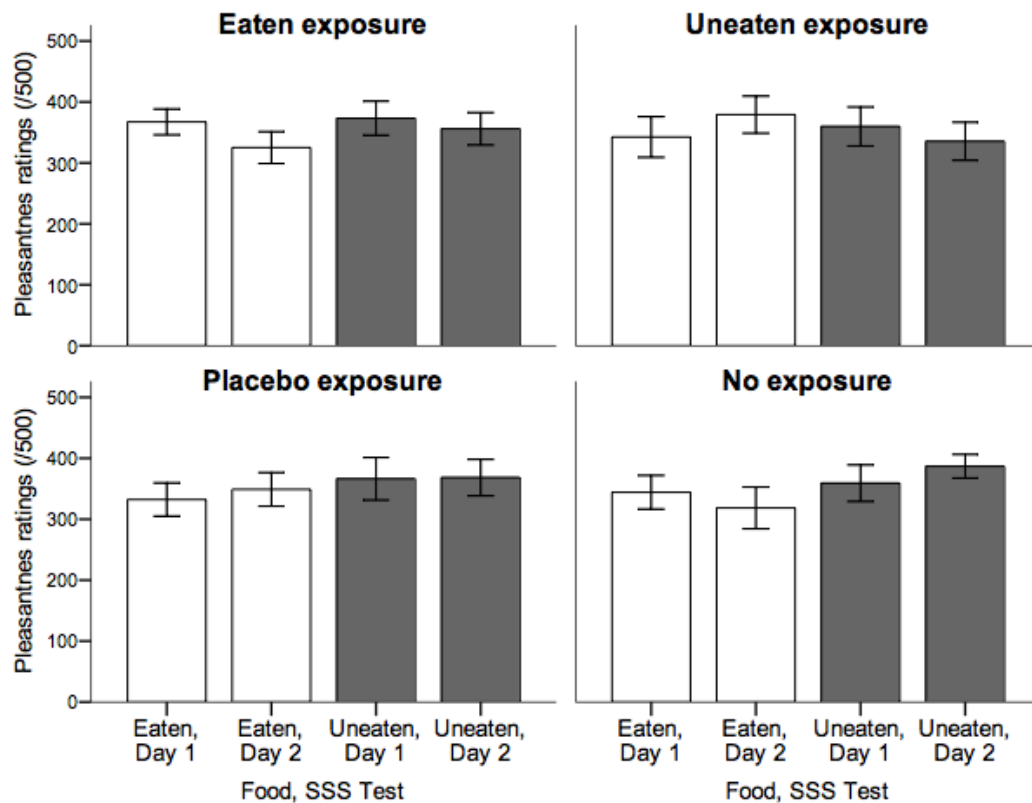


Figure 3.4: Pleasantness ratings for each food during pre-consumption phase of each SSS test for Experiment 1.

Eaten Exposure Condition

Both the Eaten and Uneaten foods decreased slightly in pleasantness post-exposure, with the decline in pleasantness ratings for the Eaten food being slightly greater than that of the Uneaten food. Whilst these results may be due to the monotony induced by exposure to the Eaten food, the effects were not statistically supported. The main effect of food was non-significant ($F(1, 14)=0.33, p=.572$) indicating pleasantness ratings did not differ greatly between the Eaten and Uneaten food. The main effect of test day was significant ($F(1, 14)=5.98, p=.028$), with both foods being rated less pleasant on the second test day. However, the change in initial pleasantness ratings between test days did not differ between the test foods (interaction food x test day $F(1, 14)=1.23, p=.285$).

Uneaten Exposure Condition

On test day 2 (post-exposure) participants in the Uneaten exposure condition rated the Eaten food as more pleasant, and the Uneaten food as less pleasant, than on test day 1. The decline in initial pleasantness ratings for the exposure food (the Uneaten test food) may be an indication of monotony induced by the exposure phase, but again this effect

was not statistically significant. The main effects of food ($F(1, 15)=0.15$, $p=.708$) and test day ($F(1, 15)=0.09$, $p=.766$) failed to reach significance, as did the interaction between food and test day ($F(1, 15)=0.99$, $p=.336$).

Placebo Exposure Condition

As expected, pleasantness ratings in the Placebo exposure condition did not differ by food ($F(1, 14)=0.33$, $p=.577$) nor by test day ($F(1, 14)=0.28$, $p=.604$), and the interaction between food and test day did not reach statistical significance ($F(1, 14)=0.24$, $p=.631$).

Control Condition

Both main effects of food ($F(1, 15)=1.48$, $p=.243$) and test day ($F(1, 15)=0.00$, $p=.942$) were non-significant, as was the interaction between food and test day ($F(1, 15)=2.79$, $p=.116$). The results support the assumption that pleasantness ratings in the control condition would not significantly differ between test foods or test days, as participants were not exposed to the test foods in the exposure phase, and thus no effect of mere exposure or monotony was induced.

3.1.3.4. Exp. 1 Sensory-Specific Satiety

To test whether SSS occurred on each test day, two separate mixed ANOVAs were conducted on Change In Pleasantness ratings during SSS testing on each experimental test day. In each analysis food (Eaten, Uneaten) served as the within-subject factor, and condition (Eaten exposure, Uneaten exposure, Placebo exposure, Control) as the between-subject factor.

Change In Pleasantness on Test Day 1

Pre-exposure on test day 1, Change In Pleasantness ratings were not expected to differ between groups as there were as yet no treatment differences between exposure conditions. However, it was expected that the Eaten food would show a significant decline in pleasantness compared to the Uneaten food, indicative of SSS. The results were in line with expectations (data shown in Figure 3.5), with an overall greater decline in pleasantness for the Eaten food than the Uneaten food, significant effect of food ($F(1, 58)=5.79$, $p=.019$), and a non-significant effect of experimental condition ($F(3, 58)=0.14$, $p=.937$). Additionally, a non-significant interaction between food and condition ($F(3, 58)=0.98$, $p=.407$) indicated that Change In Pleasantness differences between foods did

not differ significantly between conditions. Interestingly, and unexpectedly, the Placebo exposure group showed little difference in Change In Pleasantness between the test foods, and thus did not experience SSS on this occasion.

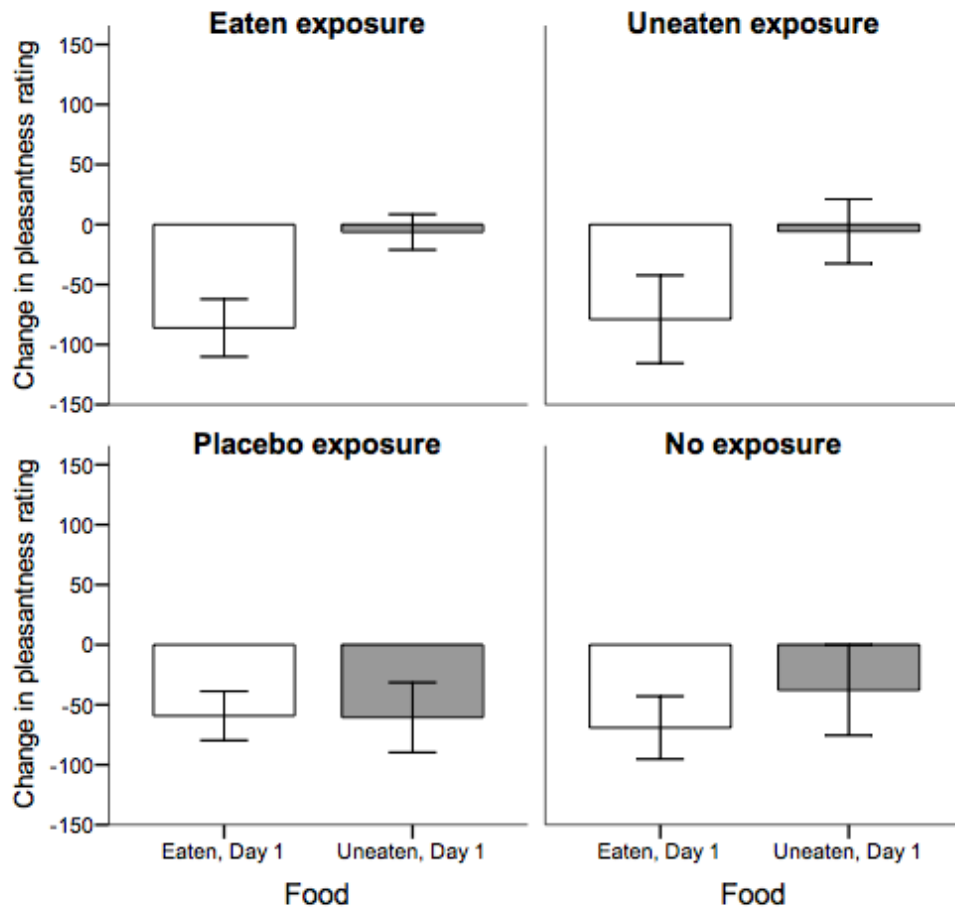


Figure 3.5: Change In Pleasantness ratings during SSS test day 1, for each of the four experimental conditions for Experiment 1.

Change In Pleasantness on Test Day 2

Sensory-specific satiety was expected to occur overall post-exposure on test day 2, but to differ between groups. The Placebo exposure and Control conditions were expected to experience SSS as normal, but the Eaten exposure and Uneaten exposure groups were predicted to express SSS differently, if mere exposure or monotony had taken place. An overall effect of SSS was evident (data shown in Figure 3.6) with the Eaten food declining in pleasantness to a greater degree than the Uneaten food (main effect of food $F(1, 58)=6.24$, $p=.015$). Whilst the main effect of exposure condition was not significant ($F(3, 58)=1.94$, $p=.133$), there was a significant interaction (food x condition $F(3, 58)=3.37$, $p=.025$) suggesting that the difference between Change In Pleasantness for the foods was

expressed differently between conditions. Again, the Placebo exposure condition displayed unexpected results, with the Uneaten food declining in pleasantness to a greater degree than the Eaten food, and the Control group showed little difference in Change In Pleasantness between foods.

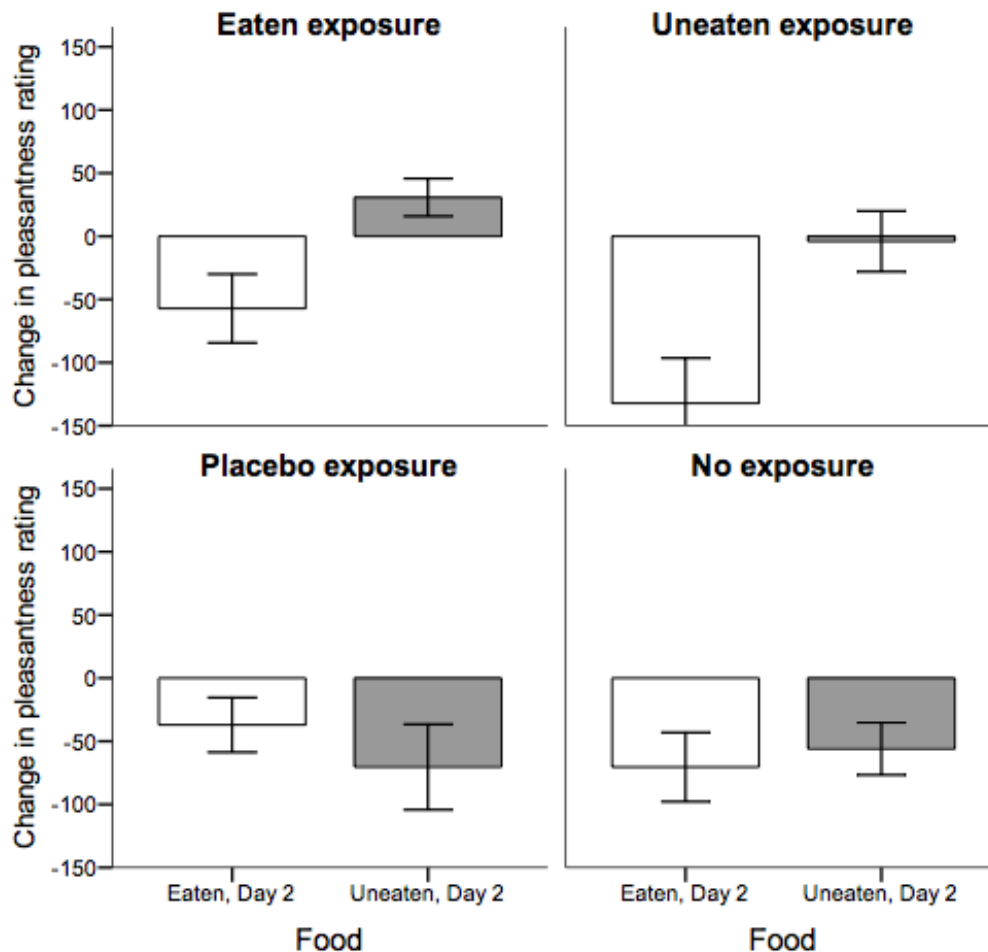


Figure 3.6: Change In Pleasantness ratings during SSS test day 2, for each of the four experimental conditions for Experiment 1.

3.1.3.5. Exp. 1 Effects of Exposure on Sensory-Specific Satiety

The experimental aim was to establish whether thirteen exposures to a novel food modulated the expression of SSS. Two analysis strategies were used, each asking a slightly different question. In the first analysis, Change In Pleasantness ratings are analysed for each food and test day, between conditions. The second analysis tests whether the magnitude of SSS (expressed as a net difference between Change in Pleasantness for the Eaten and Uneaten foods) differed between conditions across test days.

Change In Pleasantness Ratings

A mixed ANOVA was conducted on Change In Pleasantness ratings with food (Eaten, Uneaten) and Test Day (pre-exposure, post-exposure) as the within subject factors, and Condition (Eaten exposure, Uneaten exposure, Placebo exposure, Control) and as the between subject factor. The main effect of food ($F(1, 58)=9.39, p=.003$) was statistically significant, supporting an overall effect of SSS, with the Eaten food declining in pleasantness to a greater degree than the Uneaten food. The main effects of exposure condition ($F(3, 58)=0.77, p=.516$) and test day ($F(1, 58)=0.01, p=.940$) failed to reach significance, indicating little difference in Change In Pleasantness between the exposure conditions and between pre- and post-exposure. There was a significant interaction between food and exposure condition ($F(3, 58)=3.08, p=.034$), suggesting that conditions differed in the Change In Pleasantness ratings between foods. The remaining interactions did not approach statistical significance: test day x condition ($F(3, 58)=1.11, p=.353$); food x test day ($F(1, 58)=0.02, p=.880$); and food x test day x condition ($F(3, 58)=0.568, p=.57$). These results suggest that exposure conditions did not differ in Change In Pleasantness ratings between test days, that Change In Pleasantness ratings between test days did not differ by food, and that exposure conditions did not differ in Change In Pleasantness ratings between the foods across the test days.

Change in Magnitude of SSS

A potential problem with contrasting changes in pleasantness at the two stages, is that subtle differences in total Change In Pleasantness between the two foods as a measure of the extra decrease in liking through consumption may be masked by variability. As a further test of effects of exposure on SSS, a new variable (magnitude of SSS) was created by deducting the Change In Pleasantness of the Uneaten food, from that of the Eaten food on each test day. Negative valence of the magnitude of SSS would indicate a greater degree of sensory-specific satiety post-exposure, and a positive valence indicates a decline in SSS post-exposure.

A mixed ANOVA was conducted on the magnitude of SSS with Test Day (pre-exposure, post-exposure) as the within subject factor, and Condition (Eaten exposure, Uneaten exposure, Placebo exposure, Control) and as the between subject factor. Data are shown in Figure 3.7. The overall magnitude of SSS did not significantly differ between pre- and post-exposure (main effect of test day $F(1, 58)=.02, p=.880$). There was a significant main

effect of condition ($F(3, 58)=3.08, p=.023$), indicating the magnitude of SSS did differ between exposure conditions, but the non-significant interaction between test day and exposure condition ($F(3, 58)=.68, p=.568$) suggests these group differences did not differ significantly between pre- and post-exposure test days.

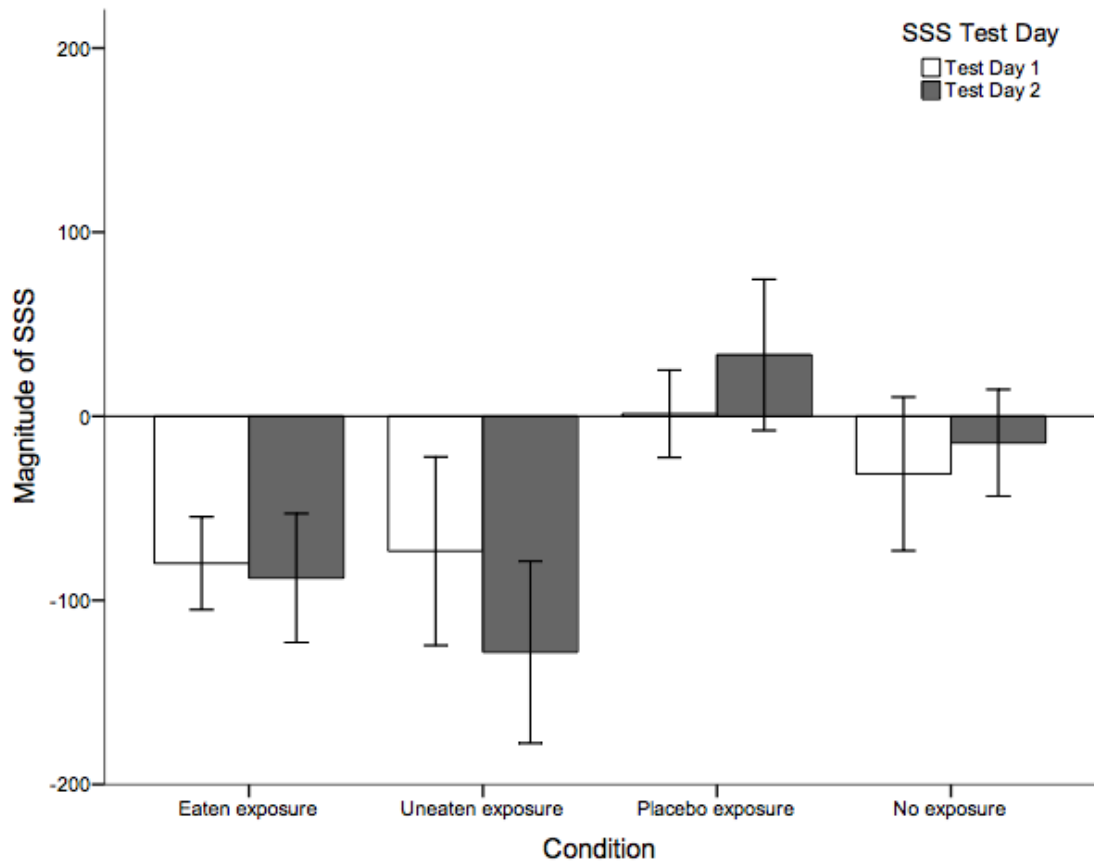


Figure 3.7: Magnitude of SSS for each exposure condition on each SSS test day for Experiment 1.

3.1.3.6. Exp. 1 Debriefing

Participants' beliefs about the purpose of the experiment were classified as follows: the effect of food on mood (41%); comparisons of the taste of two foods and/or food preference (26%); no answer / don't know (9%); miscellaneous responses[‡] (8%); the effect of a regular breakfast (3%); conditioning (3%); habituation to food (3%); and withdrawal from an addiction to the chocolate bar (3%). The last three categories totalled five participants, and these responses indicate some awareness of the experimental aims, but none were sufficiently accurate to suggest that the study was compromised.

[‡] Three participants thought the experiment was about weight-gain; two believed it to be about eating habits, and one participant thought that there was a secret camera in the waiting room, and that the experimenter was observing participants' interactions at breakfast times.

3.1.4. Exp. 1 Discussion

To reiterate, The overall aim of this experiment was to establish whether repeated exposure to novel snack foods, resulting in the development of mere exposure or monotony, would affect the extent to which sensory-specific satiety develops in a snack context. The results showed no evidence of a mere exposure effect, nor of a monotony effect, as pleasantness ratings were similar across days and between foods in the pre-consumption phases of SSS tests before and after exposure. Repeated consumption over the thirteen days did not translate into changes to hedonic ratings of the exposure food in either of the experimental conditions.

On test day 1, an overall effect of sensory-specific satiety was observed, as pleasantness ratings declined to a greater degree for the Eaten food than the Uneaten food. At this pre-exposure baseline there were no group differences in Change In Pleasantness for the foods, which was to be expected. An overall SSS effect was also observed on test day 2, although unexpectedly the Placebo exposure condition showed no SSS at all, with both uneaten foods showing a greater reduction in pleasantness ratings than the eaten food. Overall, there were group differences in the magnitude of SSS, with both the experimental groups displaying SSS to a greater degree on test day 2, but the control groups showed little, if any SSS to begin with, which actually declined further post-exposure.

Analysis of baseline novelty and pleasantness ratings supported the pilot testing results, in that the test foods were moderately pleasant, and fairly novel to the participants. In addition, there were no spurious group differences in these ratings on the first test day. It was expected that each experimental exposure condition would experience a reduction in novelty judgements for the food eaten during the exposure phase, as an indication of either mere exposure (Zajonc, 1968) or monotony. However, novelty ratings for the eaten food declined only slightly in the Eaten exposure condition post-exposure and this difference did not reach significance. The same situation occurred with the Uneaten exposure condition, with novelty ratings for the uneaten food declining post-exposure to a lesser degree, again not reaching statistical significance. As such, both these experimental groups failed to display the expected decline in novelty ratings for the exposure food post-exposure.

This experiment failed to induce either mere exposure or monotony, as measured by changes to pleasantness and novelty ratings pre- and post-exposure, and this may be for a number of reasons. A home-consumption paradigm was used to minimise arbitrary learning as a result of spurious associations between the sensory aspects of the test foods, and the laboratory setting. Previous work in this laboratory has employed a home-consumption method successfully (Mobini, et al., 2007). In that study, the test beverage was provided in sealed cans, and the stimuli would have remained fresh, with sensory properties being identical from the first portion to the last. In this experiment however, the snack bars and potato snacks were removed from their original sealed packaging and placed in press-lock plastic bags in daily portions. This was essential in order to anonymise the snacks. It is quite possible that the bags may not have been air-tight, and that over the thirteen-day exposure the snacks may have become sufficiently degraded to alter some sensory properties. If this is the case, then the sensory stimuli cannot be assumed to have been constant over the exposure phase. Minor changes in orosensory aspects may have resulted in inconsistent pleasantness and novelty ratings when fresh versions of the snack were tasted and rated on test day 2.

Successful induction of mere exposure by Pliner (1982); Crandall (1985); and Stevenson & Yeomans (1995) all employed novel foods and reported a linear relationship between exposure and increased pleasantness, and mere exposure was seen in fewer than 20 exposures. Therefore It is unlikely that thirteen consecutive days exposure to the test foods was insufficient, though it may be that the exposure foods were not sufficiently novel to begin with. Initial novelty ratings were around or below the mid-point on the 500-segment scale. Unipolar VAS were used to measure novelty, with the analytical interpretation being that any rating above zero represented some degree of novelty. In retrospect however, participants may have interpreted the scale to be bipolar, intending ratings below the mid-mark of 250 to indicate an absence of novelty. This would make the test foods unlikely to be of sufficient novelty to be sensitive to the effects of mere exposure.

Decline in pleasantness for the Eaten food may transfer to the Uneaten food, to the extent that they share sensory characteristics (see Section 1.2.1.1: Sensory-Specific Satiety in Humans). This theory would go some way to explaining the anomalous data from the group exposed to the (placebo) salty snack between test days. Thus, on the final test day, the experience of the salty snack may have led to a differential response to the sweet

foods during testing. Sensory analysis revealed that the two test foods (chocolate bar and cereal bar) differed sensorially from each other.

One final putative interpretation of these findings is that a single Uneaten food is not sufficient to highlight the greater pleasantness decline in the Eaten food, especially if both are sweet. Although SSS has been established in paradigms with only one Uneaten food (e.g. Atton, 2006), it may be that two or more Uneaten foods will work better.

Thus, in this experiment there is no evidence that exposure leads to increased or decreased SSS, but that methodological issues encountered preclude a strong conclusion that these effects may not exist under other conditions.

CHAPTER 4: The Role of Uneaten Foods in Sensory-Specific Satiety

4.1. Introduction to Experiments 2, 3 and 4

The prediction for Experiment 1 was that repeated exposure would alter the degree to which SSS developed, by way of inducing either mere exposure or monotony, and thus altering initial pleasantness ratings from the first test day to the second (pre- to post-exposure), but the results did not support this. Instead, and unexpectedly, Change In Pleasantness ratings for the Uneaten food were lower in the experimental conditions, than in the two control conditions. These findings demonstrated that exposure to the foods had a modulating effect on SSS, whilst not directly affecting baseline pleasantness (or indeed novelty) ratings of the test foods. Anomalous data from the placebo-control group (which consumed the savoury snack during the exposure) may have indicated that participants were experiencing an expectation effect during the final SSS test day. This possibility raised the question that maybe the number and type of available contrasting Uneaten foods, rather than the Eaten food (or indeed, in conjunction with the Eaten food), modulate the degree to which SSS develops, and perhaps this occurs on a cognitive level.

It was clear from Experiment 1 that SSS as a decline in pleasantness, could be induced with a single Uneaten food, and that inducement of SSS was successful despite the fact that both the Eaten and Uneaten foods were sweet snack bars, leaving the results open to the possibility of transfer effects, although as expected, there was evidence of transfer effects from the sweet Eaten food to the Uneaten food.

SSS is defined as a significantly greater decline in pleasantness for an Eaten food in comparison to Uneaten foods, and therefore comparison foods are generally presented in the SSS testing paradigm (e.g. Hetherington, et al., 1989; B. J. Rolls, et al., 1981; E. T. Rolls, et al., 1983; Vandewater & Vickers, 1996). By definition, SSS may not be established in the absence of Uneaten foods for comparison, but it could be argued that consumption of a single food will still result in significant decline in rated pleasantness against baseline (see Section 2.1: Methodology and Measurement of SSS in the Literature). Pleasantness decline for a food in the absence of unconsumed alternatives may also provide a useful benchmark against which to measure comparative pleasantness decline between conditions where the number of Uneaten foods varies.

If variation in alternative foods presents a cognitive component to the expression of SSS, systematically varying the number and type of Uneaten foods in SSS testing may well result in variation in the magnitude of SSS. The following three experiments in this chapter detail a methodological investigation, in which the goal was to establish optimum conditions for obtaining SSS in laboratory conditions by manipulating the number and type of Uneaten foods presented during SSS testing, and to ascertain whether conclusions from Experiment 1 were valid. In line with observations from Experiment 1, the expectation was that the magnitude of SSS would be modulated by cognitive expectations induced by systematically varying the presentation of Uneaten foods.

4.2. Experiment 2

4.2.1. Exp. 2 Background

Anomalous results from Experiment 1 suggest that Uneaten, comparison foods may alter the magnitude of sensory-specific satiety during testing. No previous research has reported on consumption-related pleasantness decline for a single food, in relation to the development of SSS. However, evidence suggests that exposure to a single stimulus may result in monotony (Bornstein, et al., 1990). Both monotony and SSS result in rated pleasantness decline, but a single exposure is unlikely to result in monotony unless exposure is prolonged (see Section 1.3.1.2: Monotony). Therefore decline in pleasantness in the absence of comparison foods may be attributed to SSS, rather than the effect of monotony.

The test foods in Experiment 1 were both sweet, though rated as sensorially different in pilot tests. The findings showed successful induction of SSS with just one Uneaten food, indicating that the sensory properties of the two snack bars were sufficiently dissimilar. To closely match conditions from Experiment 1 and in order to replicate the group differences observed in SSS, in this study the Eaten food presented during testing was always sweet. Uneaten foods were presented in varying numbers and combinations of sweet and/or savoury.

No measurements of long-term effects of exposure to the test foods was necessary, and the study focused on the design and implementation of SSS testing with regard to the Uneaten food manipulations. The experimental structure was a between-group design with participants attending on single test days.

4.2.2. Exp. 2 Method

4.2.2.1. Exp. 2 Design

The experiment used a between-subjects design, comparing Change In Pleasantness ratings of a sweet (eaten) snack food with other (uneaten) snack foods between five conditions. Conditions were based on the number of uneaten foods presented, and the type of uneaten foods (sweet, savoury, or both) as shown in Table 4.1.

Table 4.1: Experiment 2 Uneaten food manipulation in experimental conditions

Condition	Uneaten foods	
	Sweet (No.)	Savoury (No.)
No contrast (control)	None	None
One sweet contrast	1	None
One savoury contrast	None	1
Two contrasts	1	1
Four contrasts	2	2

4.2.2.2. Exp. 2 Participants

Inclusion and exclusion criteria for recruitment are detailed in (see Section 2.3: Participant Selection). Sixty women were recruited and randomly assigned to one of five contrast conditions, giving twelve participants in each condition. Data from four participants were excluded as they withdrew from the experiment. In all four cases, the individuals were unable to consume all of the 50g portion in the consumption phase, and in each instance the food was apple chips. The remaining sample of 56 participants' ages ranged from 18 to 31 years old (mean 22.0 ± 0.4). Height and weight data for 12 participants were missing. For the remaining 44, BMI ranged from 18.1 to 31.8 kg/m² (mean 22.7 ± 0.4). Neither age ($F(4, 51)=1.13$, $p=.352$) nor BMI ($F(4, 39)=0.89$, $p=.481$) differed significantly between the five conditions.

4.2.2.3. Exp. 2 Foods

Eight savoury, and nine sweet snack foods were piloted with the aim of selecting two savoury and three sweet test snacks that were sensorially different to maximise the chances of observing sensory-specific satiety. Thirteen women were presented with samples (3 - 5 g) of each snack in individual 50 ml clear plastic containers labelled with a number and ordered numerically on a tray. Sensory and hedonic evaluations of each food were completed using electronic VAS administered by SIPM software (see Section

2.4.1: Laboratory Setup). Participants rated each sample on the following properties: sweet; bitter; sour; savoury; crunchy; chewy; novel; and pleasant.

The aim of the pilot study was to identify three sweet and two savoury snack foods that were rated moderately pleasant (to minimise ceiling and floor effects) and highly novel (to ensure prior learning did not interfere with pleasantness ratings). A single-sample t- test was conducted on pleasantness ratings for each snack, with 250 as the test value, as this was the mid-point of the possible ratings range of 0 to 500. Snacks with pleasantness ratings significantly different from the test statistic of 250 were excluded as test food candidates for the experiment, as the pleasantness ratings were too polarised to be considered moderate. Novelty ratings were not statistically tested, as any rating above zero implies that the snack bar was novel in some way. Results are shown in Table 4.2.

Table 4.2: Mean pleasantness and novelty ratings for each snack tested in the pilot study for Experiment 2. Snacks in bold type were selected for inclusion in the main Experiment.

Savoury Snacks	Pleasantness rating	Novelty rating
Beef teriyaki crackers (Walkers)	299.1 (\pm 46.9)	292.5 (\pm 39.0)
Spanish tomato & sweet chilli biscuits (Fox's)	343.3 (\pm 42.2)*	312.2 (\pm 41.4)
Herb, garlic & ginger crackers (Jacob's)	368.7 (\pm 32.2)*	349.0 (\pm 40.0)
Sea salt sweet potato crisps (Sainsbury's)	384.8 (\pm 45.0)*	282.0 (\pm 52.4)
Caribbean chicken crispbreads (Quaker)	366.9 (\pm 36.2)*	358.6 (\pm 35.6)
Marmite biscuits (Fudges)	205.8 (\pm 51.8)	254.3 (\pm 55.9)
Worcester sauce minis (Ryvita)	318.2 (\pm 49.0)	369.7 (\pm 46.0)
Cheese & pickle bites (Go Ahead!)	335.6 (\pm 47.7)	331.3 (\pm 45.1)
Sweet Snacks		
Coconut milk chocolate curves (Cadbury's)	258.7 (\pm 52.0)	318.1 (\pm 37.7)
Fig Rolls (Sainsbury's)	308.5 (\pm 49.0)	290.6 (\pm 49.0)
Vanilla marshmallows (Sainsbury's)	210.0 (\pm 56.4)	239.3 (\pm 51.2)
Beuno (Kinder)	437.0 (\pm 37.5)*	224.0 (\pm 56.3)
Crispy apple chips (Sainsbury's)	269.7 (\pm 51.5)	305.0 (\pm 48.4)
Fudge brownies (Maryland)	327.8 (\pm 44.3)	269.3 (\pm 52.7)
Chocolate orange rice snacks (Quaker)	179.7 (\pm 43.6)	283.9 (\pm 45.4)
Milky Babies (Bassett's)	336.5 (\pm 54.0)	307.3 (\pm 33.4)
Peach & apricot cereal bar (Kellogg's Special K)	274.7 (\pm 46.3)	219.9 (\pm 44.7)

* Indicates a pleasantness rating greater than the test value of 250 ($p < .05$).

Five snacks were selected that all conformed to the pattern of results for pleasantness, and novelty which best fitted the study criteria: Beef Teriyaki Cracker (Walkers), Worcester Sauce Mini Ryvitas (Ryvita), Fig Rolls (Sainsbury's), Vanilla marshmallows (Sainsbury's) and Crispy Apple Chips (Sainsbury's). Energy and macronutrient content of the five test foods are shown in Table 4.3.

Table 4.3: Macronutrient and energy composition of the foods included in Experiment 2.

Per 100 g	Cracker	Ryvita	Fig roll	Marshmallow	Apple chip
CHO (g)	62.0	71.9	68.3	78.5	79.9
Protein (g)	1.4	6.9	4.8	4.1	2.0
Fat (g)	26.0	2.6	9.4	0.0	2.9
Energy (kcal)	490.0	339.0	377.0	330.0	354.0
<hr/>					
Per 50 g portion					
CHO (g)	31.0	36.0	34.2	39.3	40.0
Protein (g)	0.7	3.5	2.4	2.1	1.0
Fat (g)	13.0	1.3	4.7	0.0	1.5
Energy (kcal)	245.0	169.5	188.5	165.0	177.0

4.2.2.4. Exp. 2 Rating Scales

During SSS tests, all ratings were taken using electronic VAS with SIPM software (see Section 2.4.1: Laboratory Setup). Ratings were taken for appetite ('hungry', 'full' and 'thirsty'), hedonics ('pleasant') and sensory attributes ('novel', 'sweet', 'sour', 'savoury', and 'bitter') of the foods. Mood ratings were taken ('sad', 'calm', 'cheerful' and 'stressed'), but as these served only as distractors, these ratings were not analysed.

4.2.2.5. Exp. 2 Procedure

Each participant attended the laboratory on a single day for SSS testing. Participants fasted from 23:00h on the night before laboratory sessions, consuming nothing but water until arrival at the laboratory, at which point the controlled breakfast was provided (see Section 2.4.2: Laboratory Breakfasts). After breakfast, participants were free to leave the laboratory, but continued fasting (water was allowed) until they returned for testing, which took place two hours after the breakfast appointment, in a morning snack context.

Mood, appetite, sensory and hedonic ratings were completed by electronic VAS administered by SIPM software (see Section 2.4.1: Laboratory Setup), and testing was carried out in accordance with the standard SSS testing procedure (see Section 2.5: General Procedure). Samples of test foods were presented in the pre-consumption and post-consumption phases of SSS testing, the number and type (sweet or savoury) of which varied according to the relevant experimental condition. The exact snacks presented were counterbalanced within each condition. During the consumption phase of SSS testing, 50g (see Section 2.5: General Procedure) of one of the sweet sampled foods was presented (as the eaten food). The exact snack presented as the Eaten food was also counterbalanced within each condition. Regardless of experimental condition (and thus the number and type of each food presented), each snack was always presented with the same label and presented in alphabetical order on the tray (Fig rolls as Food A; Marshmallows as Food B; Apple chips as Food C; Ryvitas as Food D; and Beef teriyaki crackers as Food E). All test foods were presented at room temperature in SSS tests. At the end of the test session, participants were debriefed as to the purpose of the experiment.

4.2.3. Exp. 2 Results

4.2.3.1. Exp. 2 Change In Pleasantness Ratings of the Eaten Food

To test whether Change In Pleasantness for the Eaten food differed by the number and type of Uneaten foods presented during testing, a univariate ANOVA was conducted on Change In Pleasantness ratings for the Eaten food, with Condition (No Contrast, One Sweet Contrast, One Savoury Contrast, Two Contrasts, Four Contrasts) as the between-subject factor (data are shown in Figure 4.1).

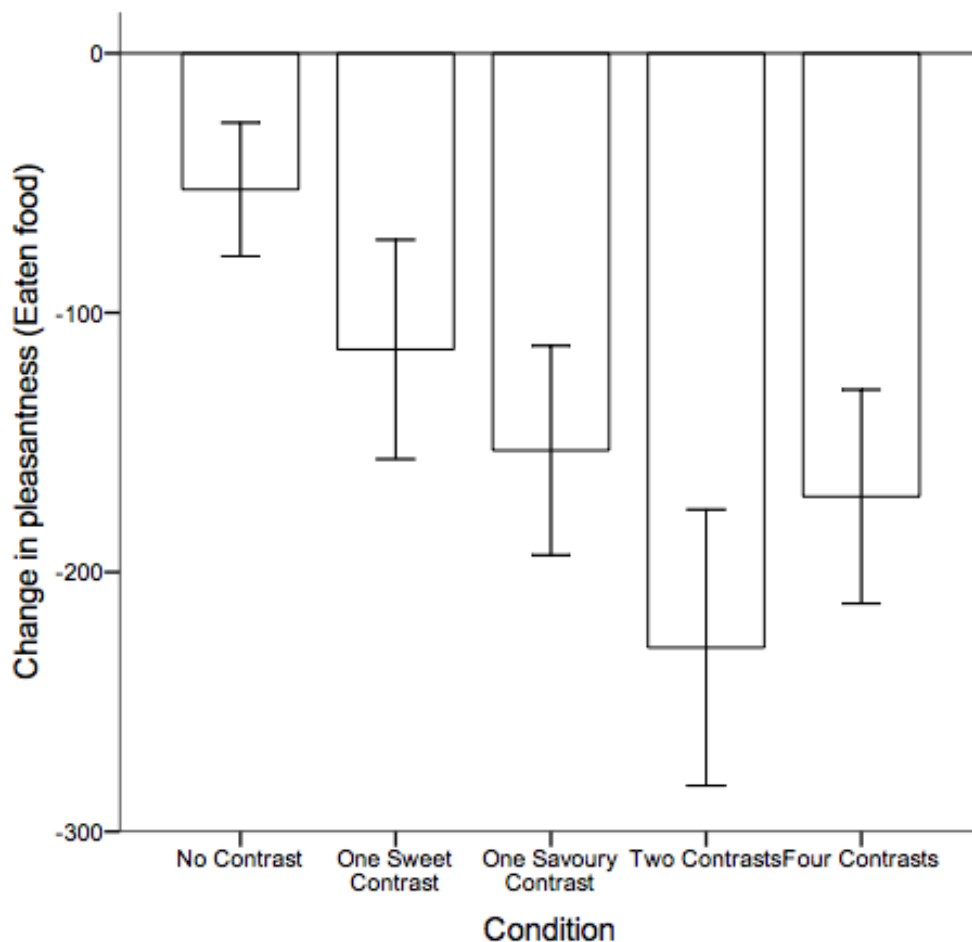


Figure 4.1: Change In Pleasantness Ratings for the Eaten food in each experimental condition for Experiment 2.

There was a significant effect of Condition on the magnitude of Change In Pleasantness for the Eaten food ($F(4, 51)=2.62, p=.046$), with pleasantness ratings for the Eaten food declining to a greater degree in conditions where Uneaten foods were present. There was a significant linear effect to the increase in Change In Pleasantness ($F(1, 51)=7.19,$

$p=.010$), with the greatest magnitude observed in the Two Contrasts condition. In addition, a significant pairwise comparison occurred between the No Contrast Condition, and the Two Contrasts conditions ($p=.034$). All other pairwise comparisons failed to reach significance.

4.2.3.2. Exp. 2 Sensory-Specific Satiety

In order to establish whether sensory-specific satiety occurred, the Change In Pleasantness for the Eaten and Uneaten foods needed to be compared. However, as the number and type of Uneaten foods varied between conditions, a single ANOVA would overlook most datasets as being incomplete. To solve this problem and maximise use of the data, SSS was analysed within each condition separately, with the exception of the No Contrast condition, as this condition had no Uneaten foods for comparison. Figure 4.2 shows the Change In Pleasantness ratings for each food by condition. In the Four Contrasts condition, ratings for the two Uneaten sweet foods and two Uneaten savoury foods have been aggregated for simplicity.

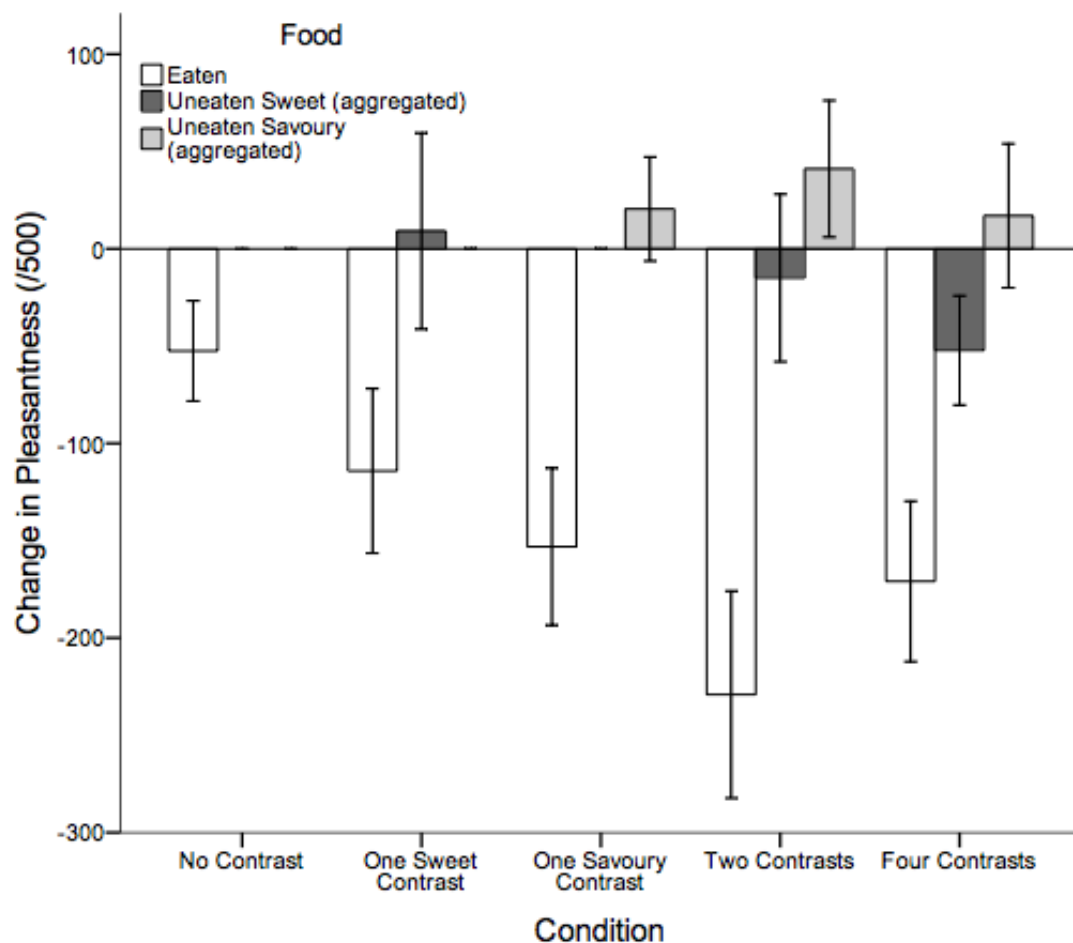


Figure 4.2: Change In Pleasantness ratings for each food in each experimental condition for Experiment 2.

One Sweet Contrast Condition

A repeated measures ANOVA was conducted on Change In Pleasantness ratings, with food as the within-subjects factor (Eaten, Uneaten Sweet). The results clearly demonstrate SSS as the Eaten food declined in pleasantness to a significantly greater degree than the Uneaten Sweet food ($F(1, 11)=16.76, p=.002$).

One Savoury Contrast Condition

A repeated measures ANOVA was conducted on Change In Pleasantness ratings, with food as the within-subjects factor (Eaten, Uneaten Savoury). As with the One Sweet Contrast condition, there was a significant effect of Food ($F(1, 10)=10.80, p=.008$) with the Eaten food showing a greater decline in pleasantness than the Uneaten Savoury food.

Two Contrasts Condition

A repeated measures ANOVA was conducted on Change In Pleasantness ratings, with food as the within-subjects factor (Eaten, Uneaten Sweet, Uneaten Savoury). As with both the One Contrast conditions, there was a statistically significant effect of food ($F(2, 20)=8.74, p=.002$), and within-subject simple contrasts (using the Eaten food as the comparison) revealed the decline in pleasantness for the Eaten food to be greater than that of both the Uneaten Sweet food ($F(1, 10)=8.27, p=.017$) and that of the Uneaten Savoury food ($F(1, 10)=11.68, p=.007$).

Four Contrasts Condition

A repeated measures ANOVA was conducted on Change In Pleasantness ratings, with food as the within-subjects factor (Eaten, Uneaten Sweet (aggregated), Uneaten Savoury (aggregated)). Once more, SSS was demonstrated, with an observed significant effect of Food ($F(2, 18)=9.57, p=.001$), and within-subject simple contrasts (using the Eaten food as comparison) show that pleasantness ratings for the Eaten food declined to a greater degree than both the aggregated Uneaten Sweet foods ($F(1,9)=7.58, p=.022$), and the aggregated Uneaten Savoury foods ($F(1, 9)=18.10, p=.002$).

No Contrast Condition

As mentioned previously, the absence of an Uneaten food in the No Contrast condition makes it impossible to test for SSS in the way it is usually operationalised (by comparing

the Change In Pleasantness ratings between Eaten and Uneaten foods). However, a decline in pleasantness ratings for the Eaten food was observed during testing, so a paired samples T-test was conducted on pleasantness ratings taken in the pre- and post-consumption phases of testing. Pleasantness ratings declined significantly between pre- and post-consumption phases ($t(11)=2.04$, $p=.033$).

These results provide clear evidence of SSS in all four tested conditions, regardless of the number or type of Uneaten foods presented during testing.

4.2.4. Exp. 2 Discussion

This experiment successfully induced SSS in each experimental condition where an Uneaten food contrast was provided. The greatest decline in Change In Pleasantness ratings for the Eaten food occurred in the Two Contrasts condition, and this outcome strongly suggests that optimal SSS is induced when the sweet Eaten food is presented with two Uneaten foods: one sweet and one savoury.

At this point it is useful to refer to the chronology of the experiments in this thesis (see Section Chapter 2: General Methods). Experiment 5 was conducted immediately after Experiment 2, and on the basis of these results, further testing of SSS in relation to dietary learning was conducted using this principal of one sweet and one savoury Uneaten food (see Experiment 5 and Experiment 6 in Chapter 5).

As predicted, monotony was not apparent in the no-contrast condition. Pleasantness ratings did not decline significantly between pre- and post-consumption in this single exposure, supporting Bornstein's (1990) model. Without pleasantness ratings for Uneaten foods for comparison, it is not possible to test SSS in the traditional way, yet pleasantness ratings for the Eaten food in the No Contrast condition did not differ significantly from baseline. Therefore, the overall Change In Pleasantness ratings for the Eaten food was not significant in that experimental condition alone, and although pleasantness did decline, it could be argued that SSS was not seen in this group. This would seem to support the continued presentation of Uneaten foods in the SSS testing paradigm (e.g. Hetherington, et al., 1989; B. J. Rolls, et al., 1981; E. T. Rolls, et al., 1983; Vandewater & Vickers, 1996), as consumption-related pleasantness decline for the Eaten food is attenuated by the absence of any available contrasts.

There is an alternative interpretation of these data however, in that the pleasantness decline in the no-contrast condition represents a baseline of SSS as consumption-related pleasantness. Further pleasantness decline arising in the other contrast conditions, and increasing in line with the number of contrasts presented, may reflect a loss of interest in consumption of the Eaten food, on the expectation that the other foods assessed beforehand may subsequently be presented in similar, singular portions. The greater pleasantness decline for two- and four-contrasts may represent an anticipatory response to the prospect of consuming additional foods. If this is the case, it raises the possibility that studies which have used multiple food samples before and after the consumption

phase in SSS experiments may have observed exaggerated pleasantness decline through this expectation-contrast effect. Whatever the explanation, the no-contrast condition proved a useful benchmark in this experiment- a control group of sorts.

Four participants withdrew from testing during the experiment. In all cases, the individuals were unable to consume all of the 50g portion in the consumption phase, and in each instance the food was the Apple Chips. The Apple Chips were a very dry snack, and 50g portion size meant that the volume of food was far greater than for the other foods used in testing at the same weight. Although data for these participants was excluded from the analyses as they were unable to complete the testing, this highlights a possible problem when selecting snacks for experimentation. There is evidence that the volume, rather than the weight of the Eaten food, is a greater predictor of SSS (Bell, et al., 2003), but this was not taken into account when establishing the fixed 50g portion for these experiments (see Section 2.5: General Procedure).

Overall, the findings from this experiment support the assumptions made about the findings from Experiment 1: that Change in Pleasantness ratings (and the resulting magnitude of SSS) can be modulated by the number and type of Uneaten foods presented during testing, and as all the test foods were of similar caloric density, and only 50g of the Eaten food was presented during the consumption phase, it is unlikely that physiological responses to the Uneaten foods could be responsible for the observed results. Therefore it is likely that the differences in Change In Pleasantness may be cognitively mediated by an expectation-contrast effect. Since this finding would lead to a fundamental redefining of the nature of SSS, further experiments were conducted to test the reliability of these results.

4.3. Experiment 3

4.3.1. Exp. 3 Background

The findings from Experiment 2 demonstrated a clear effect of number and type of Uneaten foods on the magnitude of Change In Pleasantness and SSS. This expectation-contrast effect was attributed to a cognitive element of SSS, in that pleasantness decline for the Eaten food is augmented by anticipation of consuming other, Uneaten foods after consumption of the Eaten food. Experiment 3 was conducted to establish the reliability of these findings, and to establish whether the phenomenon could be replicated when the Eaten food is Savoury. As sweet-liking is innate in humans and savoury-liking is not, the possibility remained that pleasantness changes for sweet and savoury Eaten foods may be rated differently on this basis.

Initially this work was started independently by an undergraduate psychology student as part of a final year empirical project. The design was loosely based on Experiment 2 of this thesis (see Section 4.2.2.1: Exp. 2 Design). Rather than use the test foods from Experiment 2 directly, the undergraduate piloted and selected new test foods as part of the research process. The design of the experiment was also adjusted in two further aspects. Firstly, the Two Contrasts (one sweet, one savoury) and Four Contrasts conditions employed in Experiment 2 were replaced by Two Sweet Contrasts and Two Savoury Contrasts for this experiment. Secondly, participants were not given a controlled breakfast after an overnight fast, prior to a morning testing session. Demand on laboratory space and resources at the time was limited, and meant that providing controlled breakfasts was not possible. Instead, due to constraints on undergraduate timetabling and laboratory access, individuals were asked to arrive at the laboratory in the afternoon, a minimum of two hours after they had consumed a 'normal lunch'. This alteration to the timeline of testing from Experiment 2 to this experiment was unavoidable, yet still allowed for SSS testing to take place in a snack context, albeit during an afternoon instead of a morning session.

The undergraduate project provided data from thirty participants, and the results followed a similar pattern to those from Experiment 2, with decline in pleasantness increasing in line with the number and type of contrasting foods. The findings appeared to support an increase in magnitude of SSS as a result of presentation of further Uneaten foods, and

those of a different taste (sweet vs. savoury). However, an increase in sample size was necessary to be certain of the replication of findings in Experiment 2, given the differences in experimental design noted above, so I tested an additional thirty participants, using the design, test foods, and procedures.

After completion of the additional testing, the results from the whole sample ($n=60$) no longer resembled those of Experiment two. Further investigation into the data collected for the undergraduate project exposed multiple errors in transposition from the raw text files to the SPSS data file. As a result, serious concerns arose over the integrity of the initial dataset and analyses, and the decision was made to discard all data collected from the original sample. The experiment presented here reports on the data from the second batch of thirty participants only, and is thus underpowered to some extent.

4.3.2. Exp. 3 Method

4.3.2.1. Exp. 3 Design

The experiment used a between-subjects design, comparing Change In Pleasantness ratings of a savoury (eaten) snack food with other (uneaten) snack foods between five conditions. Conditions were based on the number of uneaten foods presented, and the type of uneaten foods (sweet or savoury) as shown in Table 4.4.

Table 4.4: Experiment 3 Uneaten food manipulation in experimental conditions

Condition	Uneaten foods	
	Sweet (No.)	Savoury (No.)
No contrast (control)	None	None
One sweet contrast	1	None
One savoury contrast	None	1
Two sweet contrasts	2	None
Two savoury contrasts	None	2

4.3.2.2. Exp. 3 Participants

Inclusion and exclusion criteria for recruitment are detailed in (see Section 2.3: Participant Selection). Thirty women[§] were recruited and randomly assigned to one of five contrast conditions, giving six participants in each condition. Data from one participant was excluded from the analyses as the individual withdrew from the experiment, being unable to consume all of the 50g portion of rice cakes in the consumption phase. The remaining 29 participants' ages ranged from 19 to 42 years old (mean 26.0 ± 1.0). BMI ranged from 19.8 to 42.4 kg/m² (mean 26.0 ± 1.0). Neither age ($F(4, 24)=2.16, p=.104$) nor BMI ($F(4, 24)=1.01, p=.422$) differed significantly between the five conditions.

[§] As previously mentioned, this experiment followed on from an undergraduate project that replicated Experiment 2, with a sample size of 30 participants, and with the adjustment of the eaten foods being savoury instead of sweet. I completed testing of an additional 30 participants to ensure the results were replicable. However, serious concerns arose over the initial data, and I retrospectively felt it would be inappropriate to use the original data, hence the small sample size presented here. This decision resulted in a considerable loss of statistical power for this experiment, but the consequences were unavoidable.

4.3.2.3. Exp. 3 Foods

As the current experiment was a continuation of an undergraduate project intended to replicate the results of Experiment 2, the test foods used were those piloted and selected for the design already in use. The three savoury test snacks were: Parmesan Crackers (Sainsbury's); BBQ Rice Cakes (Quaker Snack-a-Jacks) and Sour Cream Pretzels (Penn State). The two sweet snacks (which had already been used in Experiment 2) were: Vanilla Marshmallows (Sainsbury's) and Fig Rolls (Sainsbury's). Energy and macronutrient content for all the test snacks are shown in Table 4.5.

Table 4.5: Macronutrient and energy composition of the foods included in Experiment 3

Per 100 g	Cracker	Rice cake	Pretzel	Marshmallow	Fig roll
CHO (g)	50.1	80.0	72.8	78.5	68.3
Protein (g)	14.3	7.0	9.8	4.1	4.8
Fat (g)	26.9	7.0	8.8	0.0	9.4
Energy (kcal)	499.0	416.0	413.0	330.0	377.0
<hr/>					
Per 50 g portion					
CHO (g)	25.1	40.0	36.4	39.3	34.2
Protein (g)	7.2	3.5	4.9	2.1	2.4
Fat (g)	13.5	3.5	4.4	0.0	4.7
Energy (kcal)	249.5	208.0	206.5	165.0	188.5

4.3.2.4. Exp. 3 Rating Scales

During SSS tests, all ratings were taken using electronic VAS with SIPM software (see Section 2.4.1: Laboratory Setup). Ratings were taken for appetite ('hungry', 'full' and 'thirsty'), hedonics ('pleasant') and sensory attributes ('novel', 'sweet', 'sour', 'savoury', and 'bitter') of the foods. Mood ratings were taken ('sad', 'calm', 'cheerful' and 'stressed'), but as these served only as distractors, these ratings were not analysed.

4.3.2.5. Exp. 3 Procedure

Each participant attended the laboratory on a single day for SSS testing. As the procedure for this experiment had already been set, participants were tested in an afternoon snack context, post-lunch. This differed from Experiment 2, where testing took place after a controlled breakfast in a morning snack context (see Section 2.5: General Procedure). Participants arrived at an agreed time between 14:00h and 17:00h, having previously been instructed to consume a normal lunch and then fast (water was allowed) for at least two hours prior their appointment.

Mood, appetite, sensory and hedonic ratings were completed by electronic VAS administered by SIPM software (see Section 2.4.1: Laboratory Setup), and testing was carried out in accordance with the standard SSS testing procedure (see Section 2.5: General Procedure). Samples of test foods were presented in the pre-consumption and post-consumption phases of SSS testing, the number and type (sweet or savoury) of which varied according to the relevant experimental condition. The exact snacks presented were counterbalanced within each condition. During the consumption phase of SSS testing, 50g (see Section 2.5: General Procedure) of one of the savoury sampled foods was presented (as the eaten food). The exact snack presented as the Eaten food was also counterbalanced within each condition. Regardless of experimental condition (and thus the number and type of each food presented), each snack was always presented with the same label and presented in alphabetical order on the tray (Parmesan cracker as Food A; Rice Cake as Food B; Pretzels as Food C; Marshmallow as Food D; and Fig rolls as Food E). All test foods were presented at room temperature in SSS tests. At the end of the test session, participants were debriefed as to the purpose of the experiment.

4.3.3. Exp. 3 Results

4.3.3.1. Exp. 3 Change In Pleasantness Ratings of the Eaten Food

To test whether Change In Pleasantness for the Eaten food differed by the number and type of Uneaten foods presented during testing, a univariate ANOVA was conducted on Change In Pleasantness ratings, with Condition (No Contrast, One Savoury Contrast, One Sweet Contrast, Two Savoury Contrasts, Two Sweet Contrasts) as the between-subject factor (data are shown in Figure 4.3).

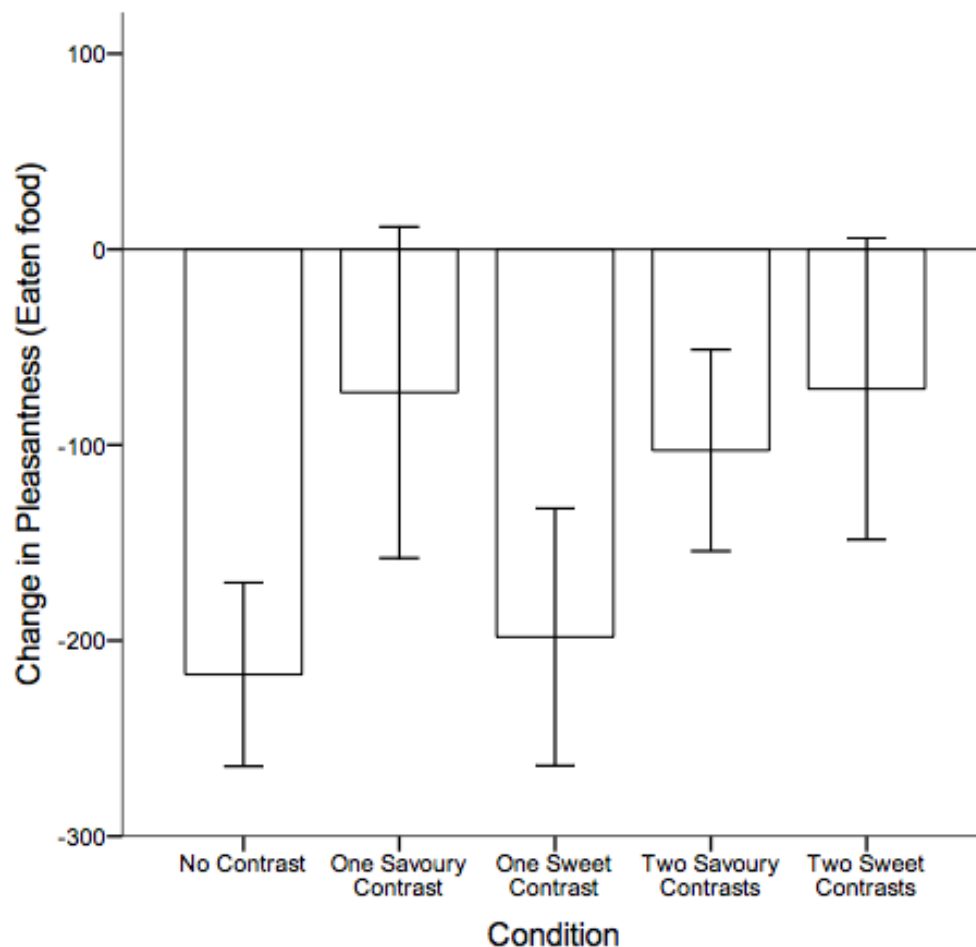


Figure 4.3: Change In Pleasantness ratings for the Eaten food in each experimental condition in Experiment 3.

The effect of Condition was not statistically significant ($F(4, 24)=1.09$, $p=.382$), demonstrating that the magnitude of Change In Pleasantness of the Eaten food did not reliably differ in regard to the number and type of uneaten foods presented in the SSS test.

4.3.3.2. Exp. 3 Sensory-Specific Satiety

In order to establish whether sensory-specific satiety occurred, the Change In Pleasantness for the Eaten and Uneaten foods needed to be compared. However, as with Experiment 2, the number and type of Uneaten foods varied between conditions and a single ANOVA would overlook most datasets as being incomplete. As with Experiment 2, to maximise use of the data, SSS was analysed within each condition separately, with the exception of the No Contrast condition which lacked Uneaten foods for comparison.

Figure 4.4 shows the Change In Pleasantness ratings for each food by condition. In each of the Two Contrasts conditions, ratings for the two Uneaten sweet foods and two Uneaten savoury foods have been aggregated for simplicity.

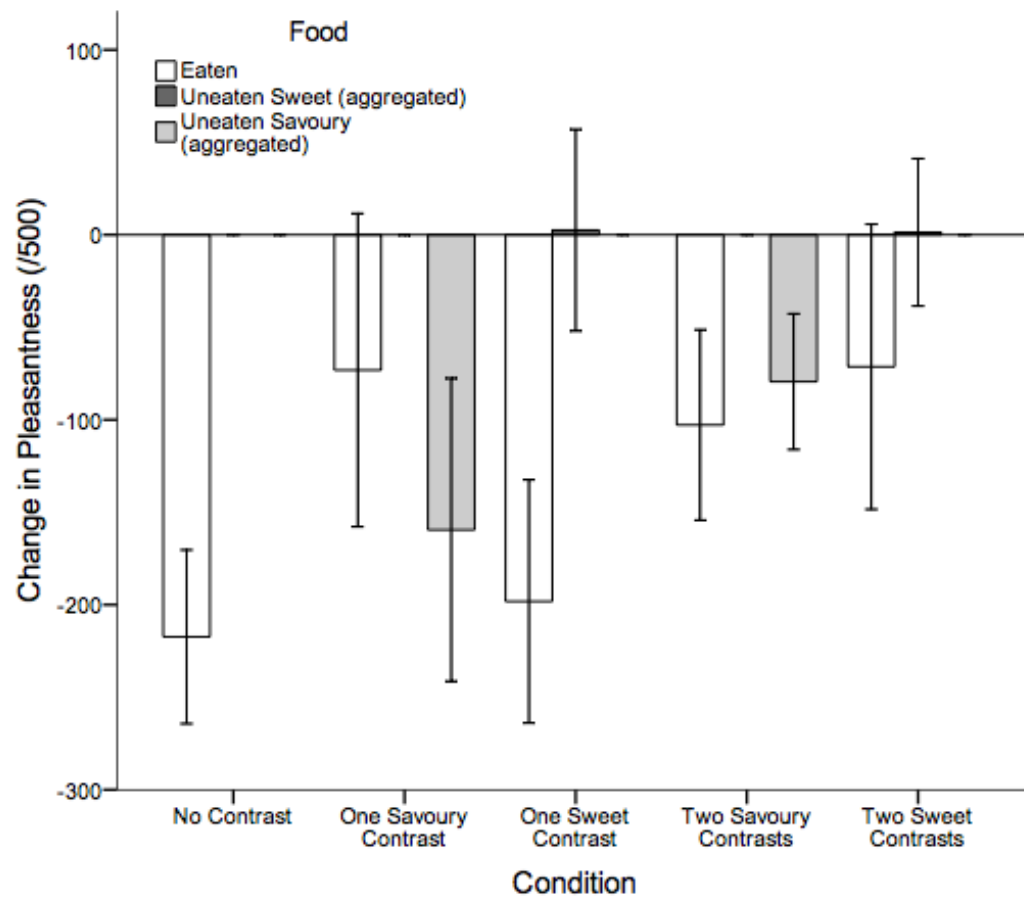


Figure 4.4: Change In Pleasantness ratings for each food in each experimental condition for Experiment 3.

One Savoury Contrast Condition

A repeated measures ANOVA was conducted on Change In Pleasantness ratings, with food as the within-subjects factor (Eaten, Uneaten Savoury). The effect of Food failed to

reach significance ($F(1, 5)=0.38$, $p=.566$) and in fact the Uneaten Savoury food declined in pleasantness to a greater degree than the Eaten food, indicating an absence of SSS.

One Sweet Contrast Condition

A repeated measures ANOVA was conducted on Change In Pleasantness ratings, with food as the within-subjects factor (Eaten, Uneaten Sweet). SSS did not occur in this experimental condition either, as there was no significant effect of Food ($F(1, 5)=3.15$, $p=.136$).

Two Savoury Contrasts Condition

A repeated measures ANOVA was conducted on Change In Pleasantness ratings, with food as the within-subjects factor (Eaten, Uneaten Savoury(aggregated)). Change In Pleasantness ratings for the Eaten and Uneaten Savoury foods did not significantly differ ($F(1,4)=0.13$, $p=.734$), providing no evidence of SSS.

Two Sweet Contrasts Condition

A repeated measures ANOVA was conducted on Change In Pleasantness ratings, with food as the within-subjects factor (Eaten, Uneaten Sweet (aggregated)). Once again there was no evidence for SSS, with a non-significant main effect of food ($F(1,5)=2.81$, $p=.155$).

No Contrast Condition

As with Experiment 2, the absence of an Uneaten food in the No Contrast condition makes an analysis of SSS impossible. As an alternative, and in line with Experiment 2, a paired T-test was conducted on pleasantness ratings taken during the pre- and post-consumption phases of testing. The Eaten food declined in pleasantness, and the change in these ratings from pre- to post-consumption was significant ($t(6)=4.63$, $p=.003$).

For each of the four conditions where an Uneaten food was presented during testing, Change In Pleasantness ratings for the Eaten food failed to decline to a significantly greater degree than the Uneaten foods, and SSS was not observed. In the No Contrast condition, the pleasantness ratings for the Eaten food declined significantly after consumption phase.

4.3.3.3. Exp. 3 Initial Hunger Ratings

Contrary to the findings in Experiment 2, this study failed to induce SSS, and the magnitude of Change In Pleasantness for the Eaten food did not depend on the number or type of contrasting Uneaten foods. One explanation may be that hunger ratings differed between conditions at the start of experimentation. In Experiment 2, participants fasted overnight and were provided with a calorie-controlled breakfast 2 hours before testing. In the present study, prior intake was not controlled to such a great degree, as participants were asked to arrive for testing at least two hours after a normal lunch. As eating habits may differ widely, it is entirely possible that differences in baseline hunger ratings at the start of the test may have confounded the Change In Pleasantness ratings recorded.

To test this hypothesis, a one-way independent ANOVA was conducted on initial ratings of hunger (taken before the pre-consumption phase), with Condition as the between-subject factor (data shown in Figure 4.5). Initial hunger ratings were fairly low, though they did not differ significantly between experimental conditions ($F(4, 24)=0.82$, $p=.525$), and mean hunger ratings in each condition were considered moderate (none near the minimum or maximum of the scale).

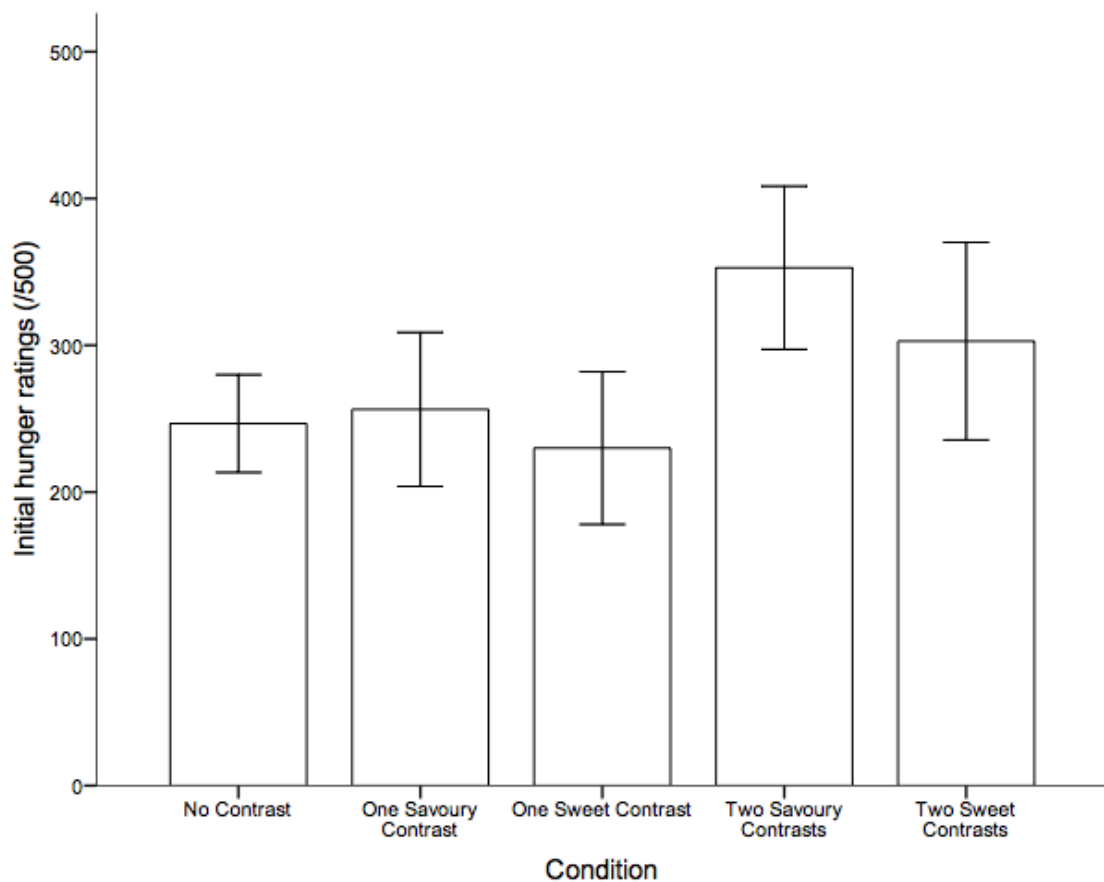


Figure 4.5: Initial hunger ratings by experimental condition for Experiment 3.

4.3.3.4. Exp. 3 Initial Pleasantness and Novelty Ratings

With group differences in initial hunger ratings having been excluded as a potential confound, there was also the possibility that group differences in the initial pleasantness or novelty ratings of the foods used during testing could be responsible for the negative findings observed.

A one-way independent ANOVA was conducted on the initial pleasantness ratings of the Eaten food, with Condition as the between-subject factor. Initial pleasantness ratings appeared to differ between experimental conditions (see Figure 4.6), with the One Savoury Contrast condition displaying a lower ratings mean in particular. Despite this, the main effect of Condition failed to reach significance ($F(4, 24)=1.08, p=.387$).

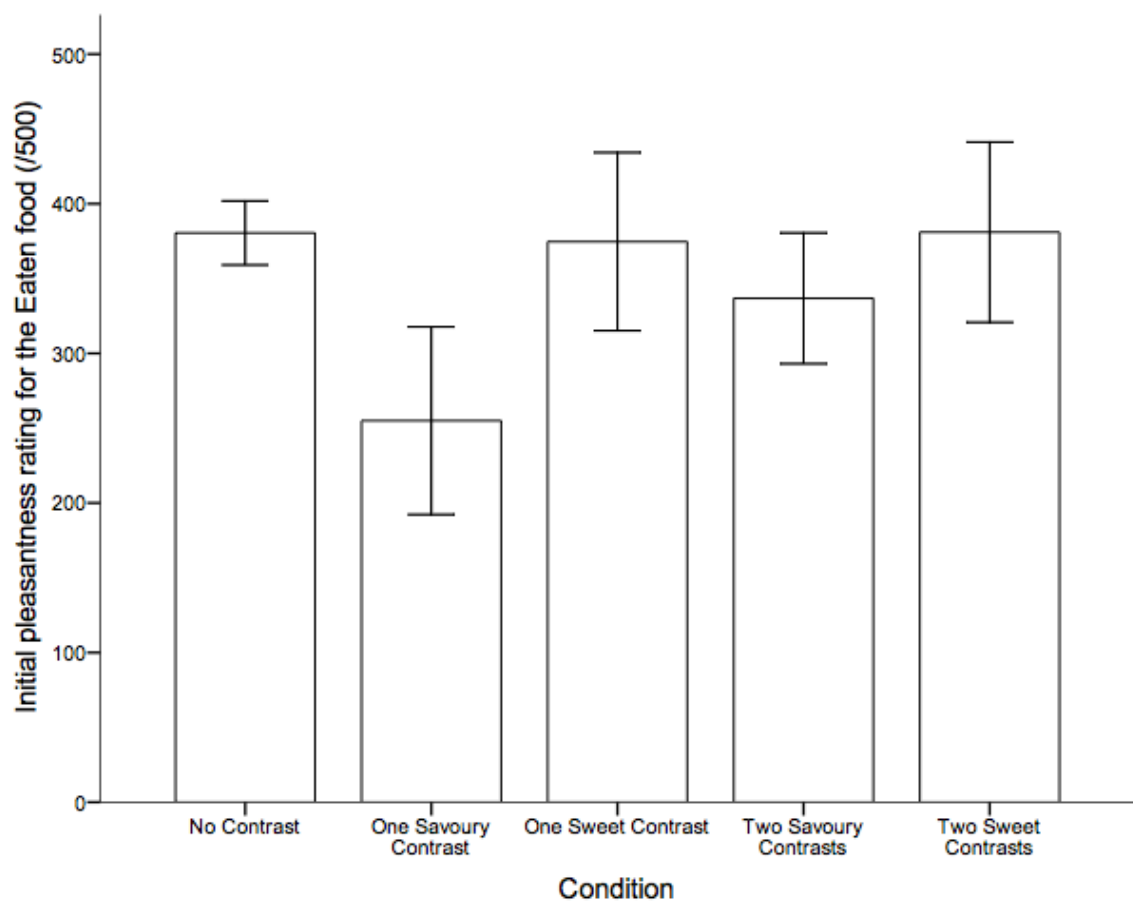


Figure 4.6: Initial pleasantness ratings for each experimental condition in Experiment 3.

A one-way independent ANOVA was conducted on initial novelty ratings (taken during the pre-consumption phase) for the Eaten food, with Condition as the between-subjects factor. A trend is apparent, with novelty ratings for the Eaten food decreasing in line with an increase in the number of Uneaten foods presented in each condition (see Figure 4.7),

however, the differences in novelty ratings for the Eaten food between groups overall did not approach statistical significance (main effect of Condition $F(4, 24)=1.48$, $p=.240$).

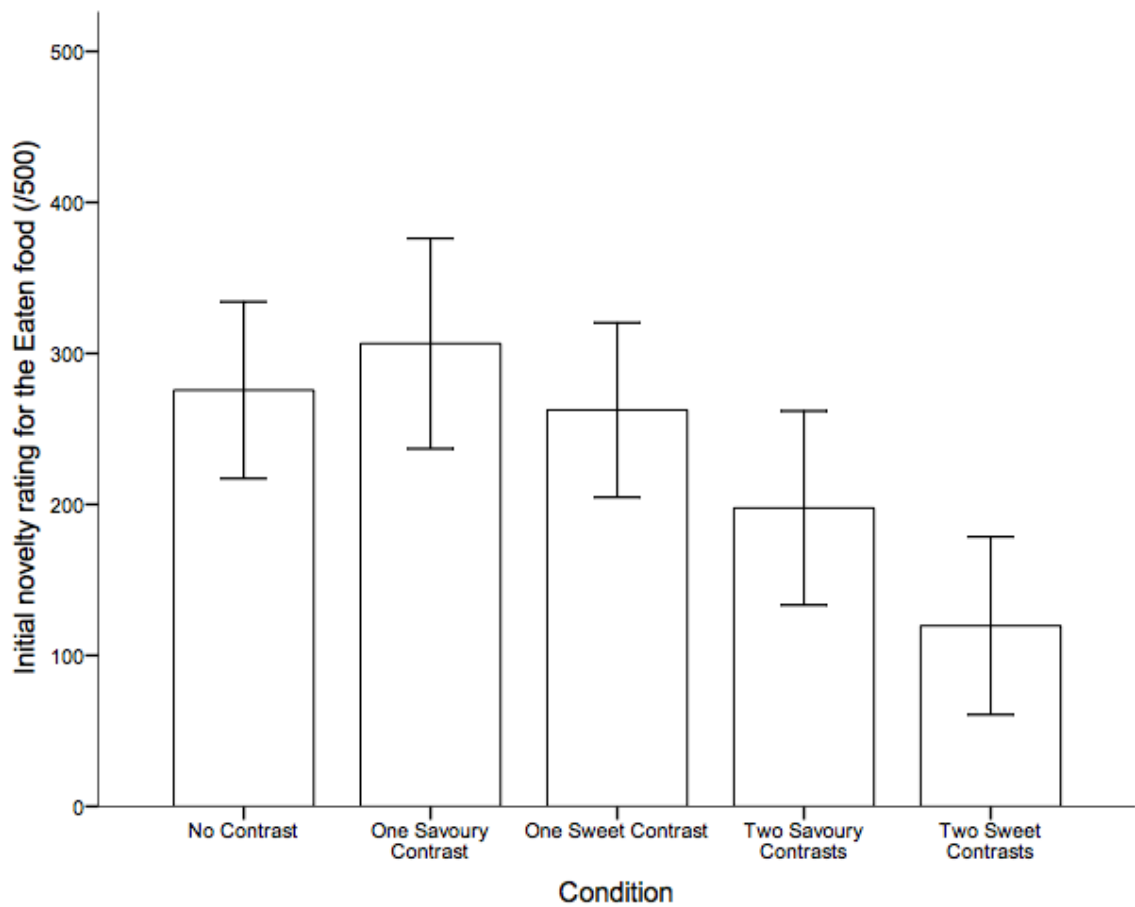


Figure 4.7: Initial novelty ratings for each experimental condition in Experiment 3.

These results suggest that while small differences in initial pleasantness and novelty ratings of the Eaten food were observed between conditions, they were not great enough to be of concern with regard to the absence of statistically-observed SSS, or the fact that the Change In Pleasantness did not differ significantly between conditions.

4.3.4. Exp. 3 Discussion

The aim of this study was to establish the reliability of the findings from Experiment 2, in which pleasantness decline and sensory-specific satiety increased significantly as a consequence of the presence of additional Uneaten foods, especially when they differed in taste (sweet vs. savoury). However, this experiment used savoury, rather than sweet snacks as the Eaten foods in SSS testing, and employed an afternoon testing paradigm with a minimum 2-hour fast post-lunch.

In stark contrast to Experiment 2 (see Section 4.2.3.2: Exp. 2 Sensory-Specific Satiety), this study failed to induce SSS in each of the experimental conditions in which Uneaten foods were presented, and no pattern emerged to indicate that the Change In Pleasantness ratings were modified by the number or type of Uneaten foods presented during testing. Additionally, and again in contrast with Experiment 2, pleasantness ratings for the Eaten food post-consumption showed a significant decline to the initial pleasantness ratings pre-consumption in the No Contrast condition. This pattern of results seems to suggest that the effect of number and type of contrasting foods is observable only when the Eaten food is sweet, and not when it is savoury.

However, there are a number of reasons why the findings here may not be relied upon. Firstly, and as noted previously, the experiment lacked power with a small sample size of only thirty participants - this could not be helped (see Section 4.3.1: Exp. 3 Background). Secondly, consumption of lunch, and interim fasting was not strictly controlled for. Individual differences in what constitutes a 'normal lunch' may go some way to explaining the lack of findings, and there was no record of what lunch was comprised of, nor the time the meal was completed for the individuals who took part. Hunger ratings taken at the start of the experiment did not differ significantly between conditions, but neither were they high. Hunger did not significantly differ from the mid-range of the 500-point range in either direction, which on the unipolar VAS employed here would indicate that participants were at least moderately hungry. Previous SSS studies have obtained positive results by testing after a 3-hour fast post-breakfast (e.g. B. J. Rolls & McDermott, 1991), as employed in Experiment 2 of this thesis, but others provide evidence that SSS is observed when testing takes place after only a 2-hour fast (e.g. Havermans, Janssen, et al., 2009). In the light of this evidence it is unlikely that hunger (or a deficiency in hunger) made a significant contribution to the absence of observable SSS.

Apparent group differences in novelty and pleasantness ratings for the Eaten food at the start of the experiment were not statistically significant, but ratings for novelty appeared to be quite low throughout. This may be a result of individual differences in interpretation of the unipolar scale, as discussed in Experiment 1 (see Section 3.1.4: Exp. 1 Discussion). From the perspective of the researcher, any moderate rating on the scale implies novelty, but participants may perceive the lower end of the scale to represent familiarity.

One participant withdrew from the experiment, being unable to consume all of the 50g portion of rice cakes in the consumption phase, replicating a possible confound identified initially in Experiment 2: that the volume of some snacks in a 50g portion is far greater than others, and whilst no other participants mentioned problems with the Rice Cake, no structured debrief took place, and therefore it may be that the fixed larger portions of the Rice Cake were off-putting. As mentioned, the design of this experiment was a continuation of an undergraduate project, and as such different methods of pilot testing may have been employed in the selection of test foods. Nevertheless, counterbalancing of the snacks presented as the Eaten food should have minimised the impact of the larger portion of Rice Cakes, and the volume of the Eaten food and its potential to confound results was taken into account in the design of Experiment 4.

The findings of this experiment failed to replicate the outcome of Experiment 2, however, the overall power was severely compromised by the unexpected need to eliminate 30 participants. Therefore it is inappropriate to conclude that the results of Experiment 2 were unreliable. Experiment 4 revisits this question in a more comprehensive way, with the aim of clarifying the effect of numbers and types of Uneaten contrast foods on the magnitude of decline in pleasantness.

4.4. Experiment 4

4.4.1. Exp. 4 Background

Results from Experiment 2 provided evidence that Change In Pleasantness ratings of a sweet Eaten food could be augmented by the number and type of Uneaten foods presented during the testing of SSS. Attempts to replicate these findings with a savoury Eaten food in Experiment 3 proved problematic, with the small sample size possibly confounding the results. Whilst the results of Experiment 3 directly contradicted the findings in Experiment 2, Experiment 3 was underpowered. In addition to this, the inclusion of Rice Cakes as an Eaten food may have presented an additional confound in the form of a portion so large in volume as to prompt a negative response from participants. Collectively, these factors meant that the experimental hypothesis may not have been addressed effectively in Experiment 3, rendering the findings unreliable.

Experiment 4 aimed to combine aspects of Experiments 2 and 3, with the aim of assessing the extent to which the presence of Uneaten foods contributes to pleasantness decline during SSS testing, and to establish if any such effect is differential between sweet and savour Eaten foods.

This study followed on from Experiment 3 (see Section 4.3.2.5: Exp. 3 Procedure), and at the time it was designed, the decision had not yet been made to discard the initial dataset in that experiment^{**}, and at that time the data as a whole suggested that 2-hour post-lunch snacking paradigm was sufficient to allow for sensory-specific satiety to be reliably induced at testing. As such, the design of this study followed the procedural pattern set in Experiment 3, with testing conducted in an afternoon snack context, and participants requested to arrive at the laboratory a minimum of two hours after having consumed a 'normal lunch'. This arrangement subsequently led to fairly low hunger ratings in this experiment (see Section 4.4.3.3: Exp. 4 Initial Hunger Ratings), but as hunger ratings from Experiment 3 (with the full data set) were higher, using the same procedure seemed sensible at the time.

^{**} The irregularities in the undergraduate data emerged after further analysis, and initial analysis of Experiment 3 found a similar pattern to that in Experiment 2. For further detail on the chronology of the experiments in this thesis, please see Section Chapter 2: General Methods.

Combining the testing of sweet and savoury Eaten foods in the current study meant that the experimental conditions could be augmented, with the One Contrast condition being duplicated to incorporate an Uneaten food that was either the same, or different to the Eaten food in terms of sweet or savoury, and Two Contrast condition was not used.

4.4.2. Exp. 4 Method

4.4.2.1. Exp. 4 Design

The experiment used a between-subjects design, comparing Change In Pleasantness ratings of an eaten snack food with other (uneaten) snack foods between eight conditions. Conditions were based on a combination of the type of eaten food (sweet or savoury) and four levels of complexity of the uneaten foods: number presented during testing (none, one, two or four) and type (sweet, savoury, or both) as shown in Table 4.6.

Table 4.6: Experiment 4 Uneaten food manipulation in experimental conditions

Condition	Eaten food Type	Uneaten foods	
		Sweet (No.)	Savoury (No.)
No contrast (sweet control)	Sweet	None	None
No contrast (savoury control)	Savoury	None	None
One sweet contrast, sweet eaten	Sweet	1	None
One savoury contrast, savoury eaten	Savoury	None	1
One savoury contrast, sweet eaten	Sweet	None	1
One sweet contrast, savoury eaten	Savoury	1	None
Four contrasts, sweet eaten	Sweet	2	2
Four contrasts, savoury eaten	Savoury	2	2

4.4.2.2. Exp. 4 Participants

Inclusion and exclusion criteria for recruitment are detailed in (see Section 2.3: Participant Selection). Sixty-four women were recruited, whose ages ranged from 18 to 33 years old (mean 22.1 ± 0.5). BMI ranged from 19.0 to 37.1 kg/m² (mean 23.6 ± 0.5). Participants were randomly assigned to one of eight contrast conditions, giving eight participants in each condition. Neither age ($F(3, 60)=1.21$, $p=.314$) nor BMI ($F(3, 60)=2.15$, $p=.103$) differed significantly between the eight conditions.

4.4.2.3. Exp. 4 Foods

As several snack foods had been piloted and tested in previous experiments in this thesis, it was not necessary to select new test foods. Six sensorially different snacks were selected which met the criteria of moderate pleasantness and novelty as demonstrated by previous results.

Three sweet foods were chosen: Peach & Apricot cereal bar (Kellogg's Special K); Apple Chips (Sainsbury's); and Fig Rolls (Sainsbury's), along with three savoury snacks: Worcester Sauce Ryvita Minis (Ryvita); Beef Teriyaki Crackers (Walkers Sensations); and BBQ rice cakes (Quaker Snack-a-Jacks). Energy and macronutrient content of the foods are shown in Table 4.7.

Table 4.7: Macronutrient and energy composition of the foods included in Experiment 4

Per 100 g	Cereal bar	Apple chip	Fig roll	Ryvitas	Cracker	Rice Cake
CHO (g)	73.0	79.9	68.3	71.9	78.5	80.0
Protein (g)	8.0	2.0	4.8	6.9	4.1	7.0
Fat (g)	8.0	2.9	9.4	2.6	0.0	7.0
Energy (kcal)	400.0	354.0	377.0	339.0	330.0	416.0
<hr/>						
Per 50 g portion						
CHO (g)	36.5	40.0	34.2	36.0	31.0	40.0
Protein (g)	4.0	1.0	2.4	3.5	0.7	3.5
Fat (g)	4.0	1.5	4.7	1.3	13.0	3.5
Energy (kcal)	200.0	177.0	188.5	169.5	245.0	208.0

4.4.2.4. Exp. 4 Rating Scales

During SSS tests, all ratings were taken using electronic VAS with SIPM software (see Section 2.4.1: Laboratory Setup). Ratings were taken for appetite ('hungry', 'full' and 'thirsty'), hedonics ('pleasant') and sensory attributes ('novel', 'sweet', 'sour', 'savory', and 'bitter') of the foods. Mood ratings were taken ('sad', 'calm', 'cheerful' and 'stressed'), but as these served only as distractors, these ratings were not analysed.

4.4.2.5. Exp. 4 Procedure

This experiment was conducted before anomalies in the undergraduate data contribution to Experiment 3 became apparent, and therefore uses the same procedure of post-lunch testing for Sensory-Specific Satiety (see Section 4.4.1: Exp. 4 Background for further details). In line with Experiment 3 (see Section 4.3.2.5: Exp. 3 Procedure), each participant attended the laboratory on a single day for SSS testing, in an afternoon snack context. Participants arrived at an agreed time between 14:00h and 17:00h, having previously been instructed to consume a normal lunch and then fast (water was allowed) for at least two hours prior to their appointment.

Mood, appetite, sensory and hedonic ratings were completed by electronic VAS administered by SIPM software (see Section 2.4.1: Laboratory Setup), and testing was carried out in accordance with the standard SSS testing procedure (see Section 2.5: General Procedure). Samples of test foods were presented in the pre-consumption and post-consumption phases of SSS testing, the number and type (sweet or savoury) of which varied according to the relevant experimental condition. During the consumption phase of SSS testing, 50g (see Section 2.5: General Procedure) of one of the sampled foods was presented (sweet or savoury, according to experimental condition). Regardless of experimental condition (and thus the number and type of each food presented), each snack was always presented with the same label (Cereal bar as Food A; Apple chips as Food B; Fig rolls as Food C; Ryvitas as Food D; Beef teriyaki crackers as Food E, and Rice cake as food F) and presented in alphabetical order on the tray. All test foods were presented at room temperature in all SSS tests.

The complexity of the study design meant that fully counterbalancing the snacks as Eaten and Uneaten test foods would have necessitated a far greater sample of participants, rendering the logistics of testing unfeasible. To avoid this situation, the Eaten foods were not counterbalanced in SSS testing: where the Eaten food was sweet, the Cereal bar was presented, and where the Eaten food was savoury, Ryvitas were presented. Neither of these snacks were presented as Uneaten foods during the experiment. In Experiments 2 and 3, there were problems with some participants being unable to consume an entire 50 g portion of some of the snacks (e.g. Apple chips), as 50 g of such foods presented as a substantial volume. There had been no previous problems of this kind with either the Cereal bar or the Ryvitas, so selecting these foods avoided previous encountered problems. The four remaining snacks were counterbalanced within relevant conditions as the Uneaten foods. At the end of the test session, participants were debriefed as to the purpose of the experiment.

4.4.3. Exp. 4 Results

4.4.3.1. Exp. 4 Change In Pleasantness Ratings of the Eaten Food

To test whether Change In Pleasantness for the Eaten food differed by the number and type of Uneaten foods presented during testing, a univariate ANOVA was conducted on Change In Pleasantness ratings, with Condition (No Contrast, One Contrast (matched to Eaten), One Contrast (opposed to Eaten), Four Contrasts,), and Eaten Food Type (Sweet, Savoury) as the between subject factors (data are shown in Figure 4.8).

There were no significant differences in Change In Pleasantness, either between groups (main effect of condition $F(3, 56)=1.18, p=.326$) or between the sweet and savoury Eaten foods (main effect of Eaten Food Type $F(1, 56)=0.67, p=.419$). Furthermore, Change In Pleasantness ratings did not differ between experimental conditions as a function of the Eaten food type (interaction Condition * Eaten Food Type $F(3, 56)=0.57, p=.635$). These findings demonstrate that the magnitude of Change In Pleasantness to the Eaten food did not reliably differ in regard to the number or type of uneaten foods presented in the SSS test.

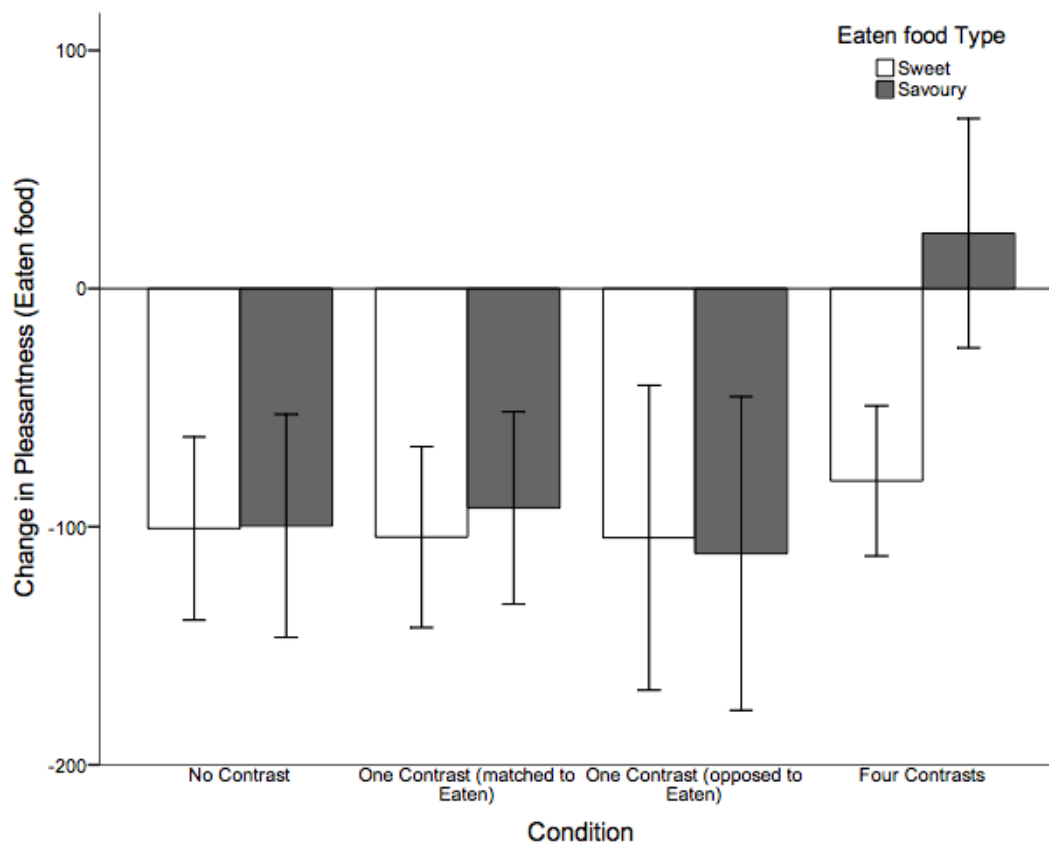


Figure 4.8: Change In Pleasantness ratings for the Eaten food for each experimental condition in Experiment 4.

4.4.3.2. Exp. 4 Sensory-Specific Satiety

As with Experiments 2 and 3, the number and type of Uneaten foods varied between conditions, and a single ANOVA would disregard most datasets as being incomplete. So once again, SSS was analysed within each condition separately, with the exception of the No Contrast condition which had no Uneaten foods for comparison. Figure 4.9 shows the Change In Pleasantness ratings for each food by experimental condition and type of Eaten food. In each of the Four Contrasts conditions, ratings for the two Uneaten sweet foods and two Uneaten savoury foods have been aggregated for simplicity.

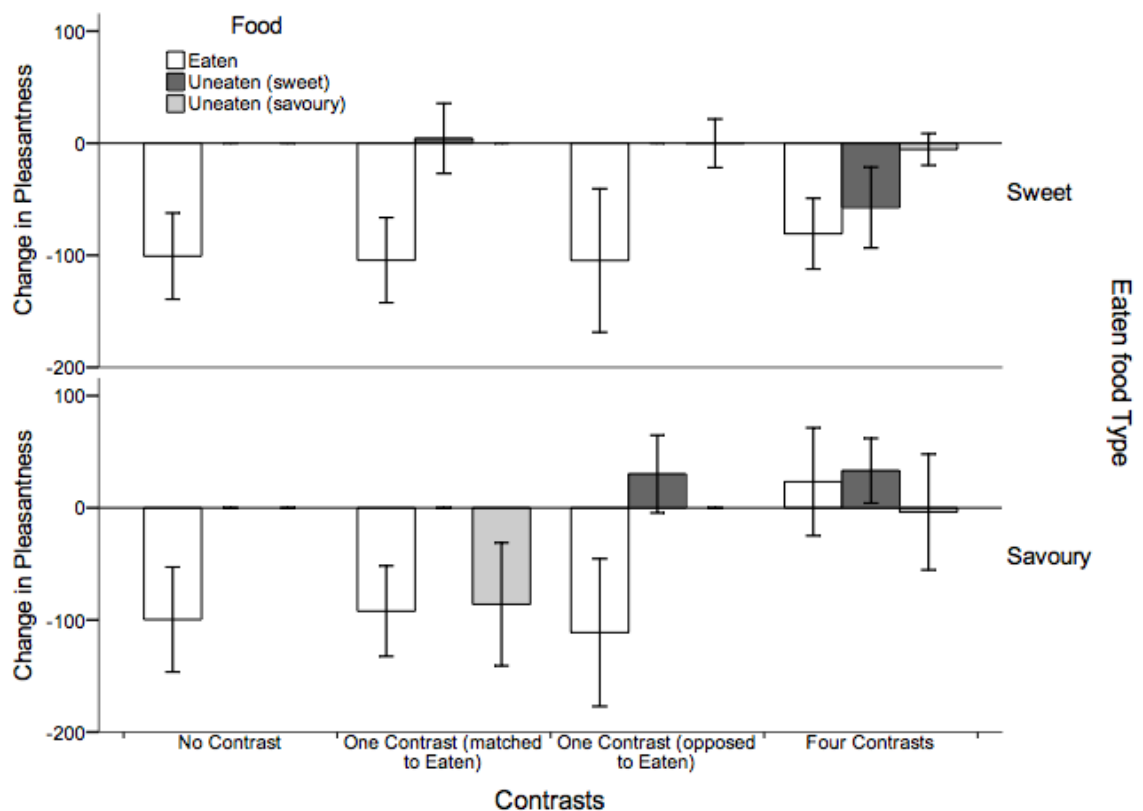


Figure 4.9: Change In Pleasantness for all foods for each experimental condition in Experiment 4.

Four Contrasts Condition (N=16)

A mixed ANOVA was conducted on Change In Pleasantness ratings, with Food (Eaten; Uneaten [sweet]; Uneaten [savory]) as the within-subject factor, and Type of eaten food (Sweet; Savoury) as the between-subject factor. Uneaten foods were aggregated into Sweet Uneaten or Savoury Uneaten.

Overall, the main effect of Food was not statistically significant ($F(1, 14)=0.35, p=.698$). As the Eaten food did not decline in pleasantness to a significantly greater degree than the uneaten foods, there is no evidence of sensory-specific satiety occurring in the Four Contrasts condition. Change In Pleasantness did not differ significantly between Sweet and Savoury Eaten foods, as reflected in a non-significant main effect of Type of eaten food ($F(1, 14)=2.59, p=.130$).

The data for the sub-groups of Type of Eaten food (Sweet and Savoury) show different trends of Change In Pleasantness for each of the foods. Where the Eaten food was sweet, pleasantness ratings declined for both the Eaten food and sweet Uneaten food, indicating a transfer effect. However, where the Eaten food was savoury, Change In Pleasantness ratings for the Eaten food were less reliable, with a mean increase in pleasantness, and a reliable mean increase in the pleasantness of the Uneaten savoury food, which again provides evidence of transfer effects. Despite the different effect of Type of eaten food on Change In Pleasantness for the three food types, the interaction between Food and Type of eaten food failed to reach statistical significance ($F(2, 28)=1.85, p=.18$).

One Contrast Conditions (N=32)

All Change In Pleasantness data for the One Contrast Conditions were analysed with a mixed ANOVA, with Food (Eaten; Uneaten) as the within-subject factor, and Condition (One-contrast matched to Eaten; One-contrast opposed to Eaten) and Type of eaten food (Sweet; Savoury) as the between-subject factors.

Overall, the main effect of Food was statistically significant ($F(1, 28)=9.27, p=.005$). The Eaten food declined in pleasantness to a greater degree than the Uneaten food, providing evidence of sensory-specific satiety in the One-contrast conditions as a whole. Overall, Change In Pleasantness did not differ significantly between conditions where the Uneaten food was matched or opposed to the Eaten food. This was reflected in a non-significant main effect of Condition ($F(1, 28)=0.42, p=.522$). The main effect of Type of eaten food also failed to reach statistical significance ($F(1, 28)=0.15, p=.710$), as there were no significant differences in Change In Pleasantness between Type of eaten food (sweet; savoury).

A trend emerged where Change In Pleasantness responses to the Uneaten food seemed to differ between the Sweet Eaten food group and the Savoury Eaten food group. When the Eaten food was sweet, both conditions displayed a small Change In Pleasantness for the

Uneaten food: when the eaten food was savoury, the Uneaten food showed a larger mean decline in pleasantness when the Uneaten food was also savoury, but a mean increase in pleasantness when the Uneaten food was sweet. Despite this observable pattern, all interaction statistics were non-significant (Condition * Type $F(1, 28)=0.51$, $p=.486$; Food * Condition $F(1, 28)=1.23$, $p=.285$; Food * Type $F(1, 28)=0.31$, $p=.592$; Food * Condition * Type $F(1, 28)=1.39$, $p=.250$).

No Contrast Conditions (N=16)

As with Experiments 2 and 3, the absence of an Uneaten food in the No Contrast condition precludes the analysis of SSS. As an alternative, all pleasantness ratings from the No Contrast conditions were analysed with a mixed ANOVA, with Time (pre-consumption, post-consumption) as the within-subject factor, and Type of Eaten food (Sweet, Savoury) as the between-subject factor.

A significant main effect of Time ($F(1, 14)=10.93$, $p=.005$) demonstrated that the pleasantness ratings for the Eaten food declined significantly after consumption during testing. However, this significant decline was not modulated by the Type of Eaten food, as indicated by a non-significant main effect of Type of Eaten food ($F(1, 14)=1.80$, $p=.201$) and a non-significant interaction between Time and Type of Eaten food ($F(1, 14)=0.00$, $p=.994$).

4.4.3.3. Exp. 4 Initial Hunger Ratings

Contrary to the findings in Experiment 2, and in line with the findings in Experiment 3, this experiment did not result in SSS, and the magnitude of Change In Pleasantness for the Eaten food did not differ between conditions, nor between the Eaten food type. As testing took place in the afternoon and participants were required to arrive at the lab at least 2 hours after a normal lunch, there was little control over intake in the previous 12-hour period. The absence of group differences in Change In Pleasantness could be attributed to baseline differences in hunger between conditions, and this hypothesis was tested statistically.

A univariate ANOVA was conducted on initial hunger ratings taken at the start of testing before any foods were presented, with Condition (number of Uneaten foods presented) and Eaten food type (sweet, savoury) as the between-subject factors (data are shown in Figure 4.10). The main effects of condition ($F(3, 56)=0.02$, $p=.995$) and eaten food type

($F(1, 56)=0.77, p=.383$) both failed to reach significance, as did the interaction between them ($F(3, 56)=0.87, p=.463$). The results indicate that initial hunger ratings did not differ significantly between conditions, nor between Eaten food type, and as mean hunger ratings in each group were not near the minimum or maximum possible ratings, all could be considered fairly moderate.

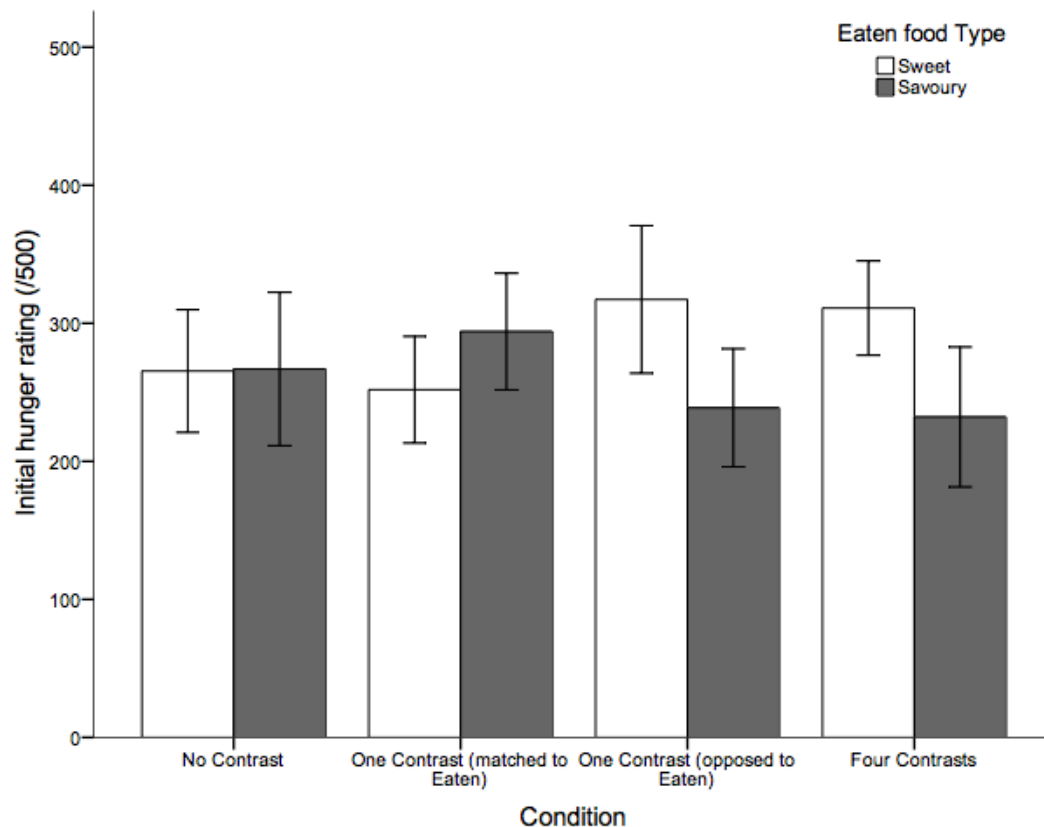


Figure 4.10: Initial hunger ratings for each experimental condition and each type of Eaten food in Experiment 4.

4.4.3.4. Exp. 4 Initial Pleasantness and Novelty Ratings

As initial hunger ratings were eliminated as a possible confound, initial ratings of pleasantness and novelty were explored to ascertain if group differences at baseline may be responsible for the absence of SSS during testing, or the failure to replicate the effect of number of Uneaten foods on Change In Pleasantness observed in Experiment 2. In Experiments 2 and 3, the Eaten food was counterbalanced within each condition. In this experiment however, counterbalancing the Eaten food would have drastically increased the necessary sample size, so the Eaten foods were restricted to the Cereal Bar (Sweet) and Mini Ryvita (Savoury) throughout the study. This approach, whilst enabling a practical sample size for testing, may, in hindsight, have been a methodological flaw and confounded Change In Pleasantness results if the initial assessment of pleasantness and novelty were either extreme, or differed between the experimental conditions.⁷⁹

As Figure 4.11 shows, initial pleasantness ratings for the sweet (cereal bar) Eaten food were similar between conditions, yet ratings for the savoury (Ryvita) Eaten food appeared to differ vastly between conditions, where ratings appear a little polarised towards either the high or low end of the scale. A univariate ANOVA was conducted on initial pleasantness ratings, with Condition and Eaten Food as the between-subject factors. The main effects of Condition ($F(3, 56)=6.00, p=.001$) and Type of Eaten food ($F(1, 56)=12.33, p=.001$) were both statistically significant, and in addition the interaction between them ($F(3, 56)=7.18, p<.001$) reached significance. This pattern of results confirms first observations of the data and provides strong evidence that the Eaten foods were rated very differently on initial pleasantness, that the ratings differed between conditions, and that the pleasantness ratings varied between the Eaten Food Types as a function of experimental condition. It is worth noting here that the mean initial pleasantness rating for the Ryvita in the Four Contrasts condition was 118.8 ± 40.8 out of a possible 500, which may have limited the potential for decline in pleasantness after consumption of the Eaten snack. This issue is discussed further in 4.4.4: Exp. 4 Discussion. Multiple comparisons were significant between the Four Contrasts condition and both the No Contrast condition ($p=.002$) and One Contrast (opposed to Eaten food) condition ($p=.006$).

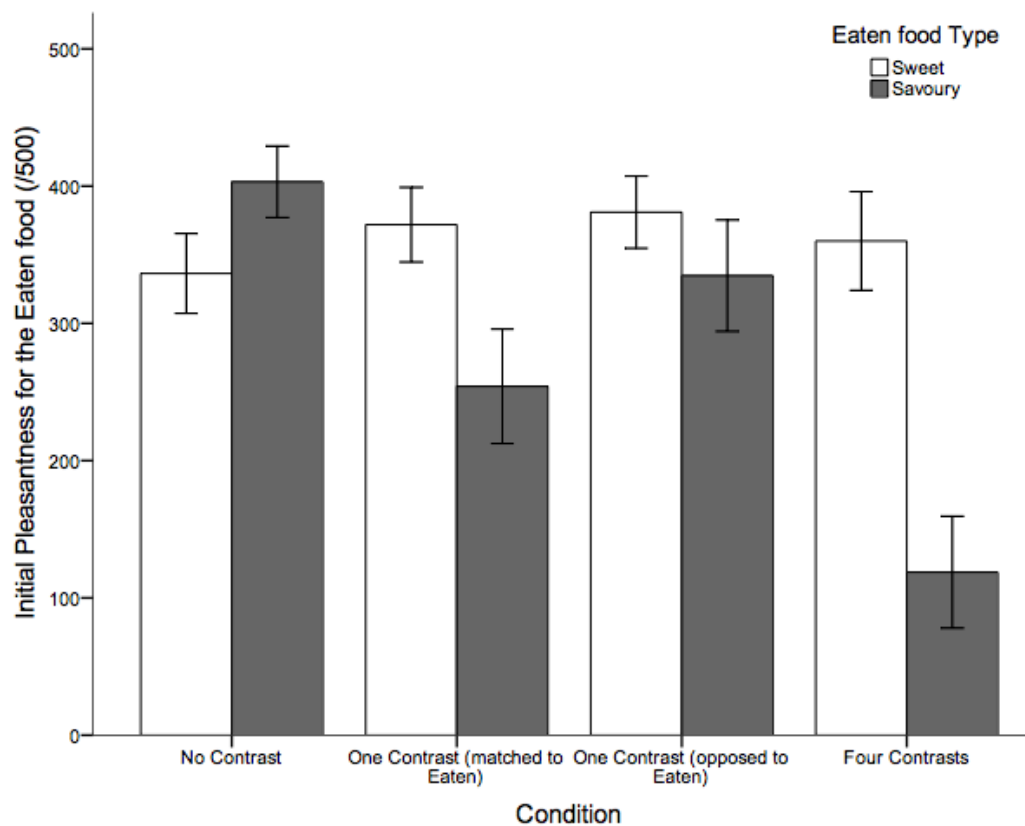


Figure 4.11: Initial pleasantness ratings for the Eaten food for each experimental condition and type of eaten food in Experiment 4.

As the data in Figure 4.12 shows, the pattern of results observed for initial novelty ratings appear as a reversal of the initial pleasantness ratings: In this instance the savoury (Ryvita) Eaten food was rated similarly for novelty between the experimental conditions, but the sweet (Cereal Bar) Eaten food appeared to differ between conditions, with particularly low ratings from the No Contrast and Four Contrasts groups. A univariate ANOVA was repeated, this time on initial novelty ratings, with the same between-subject factors of Condition and Eaten Food Type. The main effect of Condition failed to reach significance ($F(3, 56)=0.89, p=.453$), indicating no group differences in initial novelty ratings overall. The effect of Eaten Food type was statistically significant ($F(1,56)=6.80, p=.012$), with the sweet (Cereal Bar) Eaten food being rated less novel than the savoury (Ryvita) throughout the groups overall. Initial novelty ratings did not differ between the sweet and savoury Eaten foods as a function of experimental condition, though the interaction between Condition and Eaten Food Type approached, but failed to reach significance ($F(3, 56)=2.52, p=.067$).

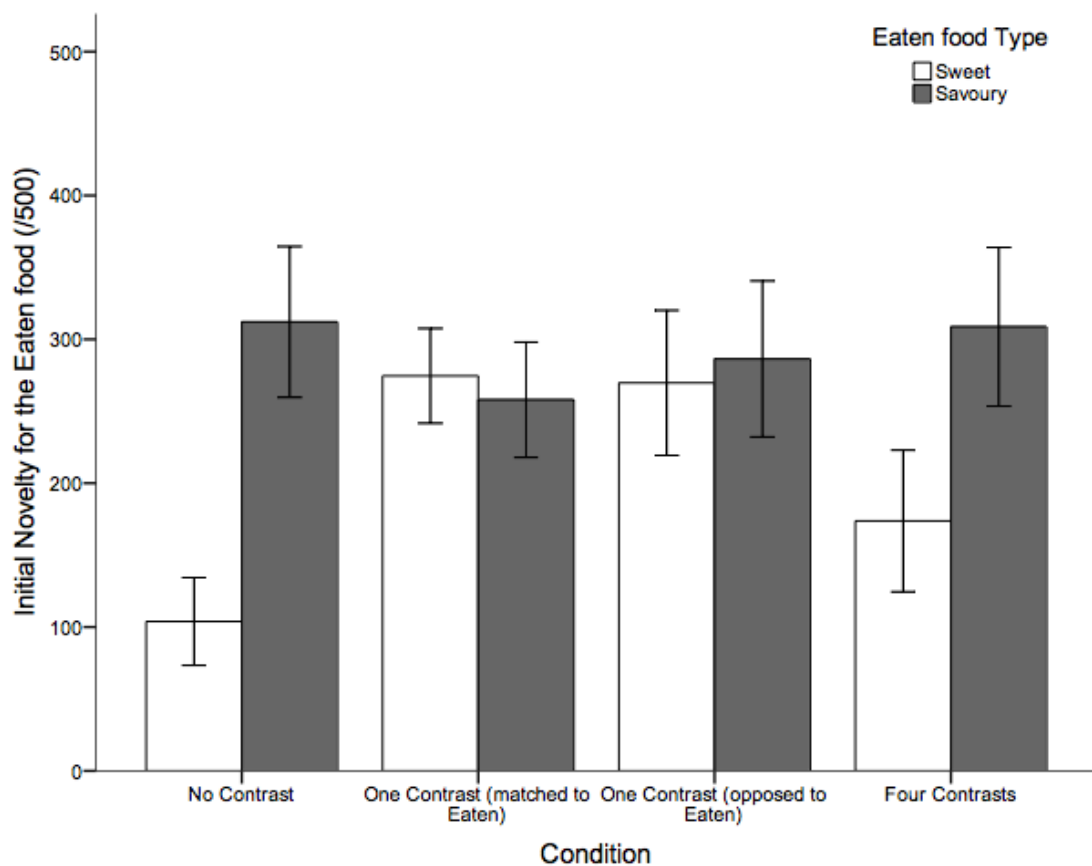


Figure 4.12: Initial novelty ratings for the Eaten food for each experimental condition and type of eaten food in Experiment 4.

4.4.3.5. Exp. 4 Initial Pleasantness and Novelty Ratings as Covariates

As anomalous results arose from analysing initial pleasantness and novelty ratings for the Eaten food in the previous section, it made sense to explore whether these spurious differences in baseline assessment of the Eaten foods could be an influence on the outcome of the analysis on Change In Pleasantness ratings. An ANCOVA was conducted on Change In Pleasantness ratings for the Eaten food, with Condition and Eaten Food type as the within subject factors, and initial ratings for pleasantness and novelty of the Eaten food as covariates. Once more, the main effect of Condition ($F(3, 54)=0.49, p=.688$); the main effect of Eaten Food type ($F(1, 54)=0.68, p=.415$); and the interaction between them ($F(3, 54)=0.00, p=1$) were not statistically significant. These results indicate that the Change In Pleasantness for the Eaten food was similar between conditions and Eaten Food type, and did not vary between conditions as a function of Eaten Food type. However, both covariates had a significant effect on Change In Pleasantness ratings: initial pleasantness ratings for the Eaten food ($F(1, 54)=5.12, p=.028$) and initial novelty ratings for the Eaten food ($F(1, 54)=4.72, p=.034$), suggesting that these factors are strongly related, at least in this study, to the magnitude of Change In Pleasantness for the Eaten food. That the results for this ANCOVA show a reduction in the effects of Condition and Eaten Food Type, when compared to the initial ANOVA conducted on these data. This indicates that any effect of number or type of contrasts previously observed has become redundant, with the initial pleasantness and novelty ratings explaining much of the variance between groups than the experimental conditions.

4.4.4. Exp. 4 Discussion

The aim of this study was to conduct a sufficiently-powered experiment to clarify the effect (if any) of the taste and number of alternative foods presented during the standard SSS testing paradigm, on the magnitude of SSS itself. As with Experiment 3, the number and type of Uneaten foods presented did not significantly affect the Eaten food decline in pleasantness during consumption, nor the degree to which SSS developed. In fact, SSS was not induced successfully in this experiment in any of the experimental conditions: the Eaten food did not decline in pleasantness, post-consumption, to a greater degree than the Uneaten food(s) presented in each and all experimental conditions.

Hunger ratings were moderate in this experiment, and not polarised in any of the experimental conditions. This is consistent with Experiment 3 (see Section 4.3.4: Exp. 3 Discussion), and again ratings of hunger did not differ between the conditions. However, the ratings were not of concern, as previous experiments have used a 2-hour fast with no detrimental impact on SSS (e.g. Havermans, Janssen, et al., 2009).

The mean initial pleasantness rating for the Ryvita in the Four Contrasts condition was 118.8 ± 40.8 (out of 500) which could be considered fairly low. This may have limited the potential for the Ryvita as the Eaten snack to decline further in pleasantness post-consumption during testing. However, pleasantness ratings for the Ryvita in the other three conditions for which it served as the test food were either moderate (254.1 ± 41.7 in the One Contrast, matched to Eaten condition), or quite high (403.1 ± 26.0 in the No contrast and 334.8 ± 40.6 in the One Contrast, opposed to Eaten conditions).

Furthermore, when the Ryvita snack was first pilot tested for pleasantness for Experiment 2 (see Section 4.2.2.3: Exp. 2 Foods), the mean pleasantness rating was 318 ± 49.0 out of 500, which was acceptable for the purposes of these experiments. Therefore, the low initial pleasantness rating for Ryvita as the eaten food in the Four Contrasts condition can be considered an anomalous result specific to this group, and whilst it may have restricted scope for pleasantness decline for this group, it is unlikely to be a factor for the other conditions.

The Ryvita was rated significantly lower in baseline novelty than the Cereal Bar. The results for the initial pilot test from which the cereal bar was selected found a greater mean novelty rating (374.5 ± 22.2) to that found in this experiment (205.5 ± 23.6). Interestingly, the No Contrast condition had the lowest rating for novelty of the cereal bar

in this experiment (although group differences on novelty ratings overall not reach statistical significance), which raises the question of whether the presence of Uneaten foods may modify ratings of novelty, in conjunction with ratings of pleasantness. It is possible that when presented on its own, the cereal bar is not distinctively novel, but in conditions where other contrasting samples were tasted, the novelty of the cereal bar became more salient because of the context in which it was presented.

As the vagaries in baseline ratings for pleasantness and novelty were explored further with the analysis of covariance, it emerged that both variables were significant covariates to the magnitude of Change In Pleasantness. Furthermore, baseline pleasantness and novelty each independently explained more of the variance in Change in Pleasantness than did Eaten food Type (sweet vs. savoury) and experimental condition combined. The pattern of these effects is not easy to discern. For example, in the No Contrast condition, Novelty was much greater for the Ryvita than the Cereal Bar; pleasantness ratings were very similar; and yet pleasantness decline was comparable between the two. In the Four Contrast condition, the Cereal Bar was rated much higher in pleasantness and lower in novelty than the Ryvita. Pleasantness decline for the cereal bar was similar to that observed for all other conditions (for both foods), but the mean Change In Pleasantness ratings of the Ryvita were positive - reflecting a general increase in ratings post-consumption, although it must be said that the variance was so substantial as to be greater than the measured change in pleasantness itself. The ANCOVA results suggest that pleasantness ratings account for a greater proportion of Change In Pleasantness than novelty ratings, at least as covariates, and the example of the Four Contrast group supports this.

In hindsight, the decision not to counterbalance the Eaten foods may have been a serious methodological flaw in the design of the experiment, for two reasons. Firstly, there were significant differences in initial ratings of novelty and pleasantness between the experimental conditions, providing possible confounds at baseline. Secondly, initial ratings for both pleasantness and novelty of the Eaten foods explained the greater part of the variance in any group differences in Change In Pleasantness ratings. Both these confounds may have been reduced or eliminated completely, if the Eaten food had been counterbalanced.

Overall, these findings show that when the Eaten food was sweet, that the decline in pleasantness post-consumption was similar across conditions, but low in all of them.

With the exception of the Four Contrasts condition, the pleasantness ratings for the Eaten food declined to a greater degree than the Uneaten food(s), though analysis revealed that these differences were not statistically significant. This pattern is similar to Experiment 2, where SSS was reliably induced with a sweet Eaten food. Results for the savoury Eaten food appear to support those of Experiment 3, where the findings revealed no reliable reduction in pleasantness of the Eaten food, and no significant manifestation of SSS. Thus, the possibility of differential effects of type and number of eaten food on consumption-related pleasantness decline in SSS had not been ruled out, though methodological problems meant that the experiment ultimately failed to provide reliable evidence either way.

4.5. General Discussion of Experiments 2, 3 and 4

The three experiments presented in this chapter comprise a methodological investigation into the presentation of Uneaten snacks at the start and end of sensory-specific satiety tests in the laboratory. Anomalous findings from Experiment 1 (see Section 3.1.4: Exp. 1 Discussion) appeared to suggest that there was an expectation effect exerting an influence on the magnitude of SSS, and that the expectations were linked to the possibility of consuming alternative foods. In the standard SSS paradigm multiple Uneaten foods are presented for tasting and rating pre- and post-consumption of the Eaten food (e.g. Hetherington, et al., 1989; B. J. Rolls, et al., 1981; E. T. Rolls, et al., 1983; Vandewater & Vickers, 1996). Experiments 2, 3 and 4 systematically varied the number and type (sweet vs. savoury) of Uneaten foods presented during testing, with the objective of verifying whether the magnitude of SSS was modulated as a result.

Experiment 2 used sweet snacks only as the Eaten food, and successfully generated SSS in all conditions: pleasantness decline was greater for the Eaten food than the Uneaten foods. A limited decline in pleasantness of the Eaten food was observed in the No Contrast condition, and the magnitude of decline increased in line with the number of Uneaten contrasts, with an apparent optimum of two Uneaten foods (one sweet and one savoury). Attempts to replicate these findings with a savoury Eaten food in Experiment 3 were hampered by a reduced sample size and methodological flaws which resulted in the experiment being an insufficient test of the hypotheses. Experiment 4 was initiated to clarify conflicting results of two previous experiments: to test the effect of number and type of Uneaten contrasts on Change in Pleasantness ratings of the Eaten food (savoury vs sweet), and on the development of Sensory-specific satiety. The experiment mirrored much of the procedure from Experiment 3^{††} however, and so inherited some of the same design flaws. As a result, this final experiment fell short of supporting the initial data from Experiment 2, but confirmed some of the methodological issues encountered in Experiment 3.

^{††} Experiment 4 was designed before the decision was made to discard data from Experiment 3, a decision which subsequently exposed some methodological flaws in analysis of the reduced dataset. By the time these issues came to light, data collection was already underway for Experiment 4. See Section 4.3.1: Exp. 3 Background for a full explanation, and Section Chapter 2: General Methods for the chronology of experiments.

Putting aside methodological differences, the findings from these three experiments are inconsistent in various respects. In particular, the decline in pleasantness for one food when eaten alone presented differing results. As previously discussed, it is not possible to measure SSS *per se* when there are no Uneaten foods with which to contrast the decline in pleasantness for the Eaten food - a statistical necessity that defines SSS. Therefore, only decline in pleasantness from baseline was used as measurement for these groups: a difference that met statistical significance in Experiments 3 and 4, but not in Experiment 2. In addition to this, the magnitude of pleasantness decline for the Eaten food in the other conditions varied across experiments. Experiment 2 showed the greatest decline in the Two Contrasts group, and was similar in magnitude to the No Contrast and One Sweet Contrast groups in Experiment 3. In Experiment 4, decline in pleasantness was consistent across the Eaten foods and experimental conditions (with the exception of Ryvita in the Four Contrasts condition, as discussed), and was approximately half that of the optimum decline demonstrated in Experiment 2. An additional analysis conducted on data from Experiment 4 demonstrated both baseline pleasantness and novelty as significant covariates. Therefore the observed variations in Eaten food pleasantness-decline across experiments may be driven by the baseline pleasantness and novelty ratings of the foods. Another complicating factor is the absence in the last two experiments of a two-contrast condition in which one sweet and one savoury food are presented. This condition manifested the greatest degree of SSS in Experiment 2, but because it was not picked up in Experiment 3, for reasons explained above it was also not included in the design of Experiment 4.

Experiments 3 and 4 presented only moderate ratings of hunger (analysis not conducted on Experiment 2), although these were not polarised in any individual condition, and did not differ significantly between conditions. Liking may be linked to hunger, for Example Mobini *et al* (2007) found that a novel flavour paired with sugar received higher pleasantness ratings pre-lunch, than post-lunch. If hunger were not great enough in these experiments, it may have restricted initial pleasantness ratings, resulting limited scope for SSS development. However, SSS develops reliably after a 2-hour fast of the type used in Experiments 3 and 4 (e.g. Havermans, Janssen, et al., 2009), and there was at least some pleasantness decline observed, the results of these experiments are better explained by baseline pleasantness and novelty ratings.

The Eaten food was presented as a 50g portion in all instances, which presented difficulties with two of the test foods. Apple Chips (four participants withdrew from

Experiment 2, unable to consume the whole portion) and the Rice Cakes (One participant withdrew from Experiment 3 for the same reason)) proved to be voluminous portions, especially in comparison to the other snacks (e.g. cereal bar, and fig rolls). However, marshmallows, parmesan crackers and pretzels also presented visually large portions at 50g, but did not appear to be so off-putting to participants. This apparent difference in acceptance of the consumption portion between snacks could be driven by snack differences in the effort required to eat them. Previous research demonstrates that the duration of oral exposure during consumption contributes to pleasantness decline (Smeets & Westerterp-Plantenga, 2006); and that the volume consumed contributes more to pleasantness decline than does the weight of the portion (Bell, et al., 2003). The implications of these studies were not fully taken into account when designing Experiments 1 and 2, having already decided upon a 50g portion size to be consistent throughout the research for this thesis. However, initial rated pleasantness is likely to be instrumental in differentiating between whether a large portion results in greater SSS (e.g. if the food is liked), or in avoidance (e.g. if the food is not liked). The process of consuming a 50g portion of a voluminous snack will no doubt polarise pleasantness still further. The issue of portions being too great to be consumed did not arise in Experiment 4.

In conclusion, the findings of Experiment two, where the number and type of Uneaten foods were found to contribute to the magnitude of SSS have not been replicated, but equally, have not been refuted. The issues encountered in the methodology of Experiments 3 and 4 have revealed that the development of SSS may be related to baseline pleasantness and novelty ratings of the Eaten food. The results also show that the reliability of inducing SSS in laboratory conditions relies heavily on selecting the right test foods, portion sizes, and hedonic characteristics. Thirdly, systematic counterbalancing of the Eaten food is essential in these between-subject studies, in order to minimise the potential impact of individual differences in ratings. A fourth and final valuable lesson learned from these three experiments, is that results of pilot testing seems to bear little resemblance to experimental results of ratings for pleasantness and novelty, and future experiments should take this into account.

CHAPTER 5: Flavour-based Learning, Learned Satiety and Sensory-Specific Satiety

5.1. General Introduction to Experiments 5 and 6

Experiments 5 and 6 present the final investigations of the thesis, and signify a return to the original aims of the research: to determine whether long-term hedonic changes arising from dietary learning affect the magnitude of SSS. The process began with Experiment 1, which set out to record the effects of mere exposure and monotony on the magnitude to which SSS develops for a novel food. The objective was to clarify the extent to which repeated exposure in the absence of experimental-induced reinforcement modified the magnitude of SSS; and thus to provide a baseline for comparison in the following experiments where dietary learning was a principle manipulation. The experiment failed to find any reliable evidence of either mere exposure or monotony, and instead raised questions about the effect of Uneaten foods on SSS, in the form of expectations generated by the presence of contrasting foods in the pre-consumption phase. Experiment 2 was the start of a three-experiment inquiry into the nature of this effect, and the findings suggested that optimum consumption-related pleasantness decline could be achieved with two Uneaten foods, one sweet and one savoury. These findings set the design for further SSS testing in Experiment 5, and in Experiment 6.

SSS has so far been explained by habituation to the eaten food (albeit within an eating episode, i.e. mouthfuls), but the outcome of earlier studies in this thesis (see 4.2: Experiment 2) suggest that other factors may also be at work. An alternative theoretical explanation for SSS is that it may be, at least in part, an expression of prior learning about the satiating effects of different foods. Initial pleasantness can be enhanced by “mere exposure” (Zajonc, 1968), which results in an increase in pleasantness of a previously novel stimulus after exposure. However, Experiment 1 (see Chapter 3.1.4: Exp. 1 Discussion) found no evidence that repeated exposure to a novel food had any effect on the magnitude of SSS generated by the exposure food, and in fact the findings demonstrated no significant post-exposure changes in pleasantness.

Food pleasantness ratings are subject to modulation by learned associations. If the association is formed between the sensory properties of the a food stimulus that is already liked (e.g. sweetness, or a previously preferred flavour), and the sensory properties of a novel food stimulus, hedonic valence from the known flavour is transferred to the novel

flavour over the course of repeated pairings (e.g. Brunstrom, et al., 2001; Brunstrom & Fletcher, 2008; Brunstrom, et al., 2005; Brunstrom & Mitchell, 2007; Yeomans, Gould, et al., 2008; Yeomans, et al., 2007). This effect is termed Flavour-Flavour Learning (FFL - see Section 1.3.3.1: Flavour-Based Learning). When the learned association links the sensory aspects and the consequences of consumption of a food stimulus (e.g. Brunstrom & Mitchell, 2007; Chambers, et al., 2007; Mobini, et al., 2007; Tinley, et al., 2003; Yeomans, Durlach, et al., 2005), a phenomenon known as Flavour-Consequence Learning (FCL - see Section 1.3.3.1: Flavour-Based Learning). Changes to liking acquired in this manner can occur in a negative way, such as learning to avoid foods that make us ill (conditioned food aversion), or in a positive way – such as learning to like a flavour that has previously been associated with a high-energy intake (conditioned flavour preference).

At the time these experiments were conducted, there were no published studies that explicitly explored how changes in liking induced by FFL and FCL alter the degree to which SSS develops when a novel food is consumed post-learning. Two rather different learning effects may be important here. The first, captured by the broader concept of FCL, might impact on initial pleasantness evaluation, with increased initial liking for the flavour of foods which have been found to have positive post-ingestive consequences. The second is that of learned satiety (Booth, 1972): control exerted over meal size in anticipation of the satiating effect of the stimulus food. Repeated consumption of a food which varies little in energy-density results in an association between the sensory properties and post-ingestive satiating effect of the food. Changes in the degree to which SSS develops are a plausible mechanism to explain any such learned adjustments in meal size, but this idea has never been explored experimentally. The overall aim of the experiments described in this chapter was to explore the potential role for these different learning mechanisms in the development of SSS.

Whilst SSS appears not to be subject to modulation by the energy density of foods (e.g. B. J. Rolls, Hetherington, et al., 1988a), there is some evidence that SSS may develop to a greater degree with foods that have a high protein content (e.g. Vandewater & Vickers, 1996). The reason for this is unclear, but may be due to the effects of prior learning about the satiating effect of the experimental foods: protein is more satiating than fat or carbohydrates (see Section 1.2.2.3: Energy and Macronutrient Content). Thus the finding of greater SSS with high-protein foods would be consistent with a role for learned satiety and FCL in expression of SSS, but because these studies did not explicitly use a learning

model, but rather contrasted SSS between different foods, these data cannot be taken as strong evidence for a role of learning. The research in this Chapter therefore uses more explicit tests of the role of learning.

The two experiments presented in this chapter explore the potential interface between sensory-specific satiety and dietary learning in the form of FFL, FCL and learned satiety.

5.2. Experiment 5

5.2.1. Exp. 5 Background

Experiment 5 was designed to explore the effect of acquired liking for a food, established by repeated pairing of a novel dessert with high-energy, on the magnitude of SSS. Zajonc's (1968) observations on the effect of mere exposure found that repeated exposure in the absence of reinforcement resulted in elevated liking for the test stimuli, and that the effects were stronger with novel flavours. Novel stimuli by definition will have no prior learning associated with them, and will therefore be more susceptible to changes in pleasantness ratings over the course of several encounters. Findings from other experiments provide support (e.g. Pliner, 1982 see Section 1.3.1.1: Mere Exposure). In order to maximise the prospect of observing changes to baseline pleasantness ratings in this experiment, a novel dessert-like snack food was developed specifically for this study. Two versions were created: high- (HED) and low-energy (LED), matched during pilot testing for moderate rated pleasantness and sensory properties. Both versions of the test food were low in carbohydrates, and the energy differences between the two were made up with 50% protein and 50% maltodextrin (carbohydrate). Protein is the most satiating macronutrient (see Section 1.2.2.3: Energy and Macronutrient Content) and therefore ideal for inclusion in a test food intended to induce energy-related learning. However, protein has a slightly 'grainy' texture that makes it easily detectable in an otherwise smooth textured food, such as the test foods here. Using carbohydrate to contribute to the energy difference was a compromise that allowed the two versions of the snacks to be better matched for sensory properties, and for the protein to be more readily disguised in the HED food.

Two groups of participants consumed a 200g portion of either the HED or LED food on eight non-consecutive days, with the aim of generating long-term pleasantness changes from Flavour Consequence Learning (FCL) from association between the novel flavour and post-ingestive energy yield – a paradigm similar to that used in other learning experiments (see Section 1.3.3.1: Flavour-Based Learning).

SSS testing took place on three occasions (prior to the first exposure; and after four; and after eight exposures). In each SSS test session the low-energy version of the novel food was presented as the Eaten food, to ensure that any observed changes to pleasantness

decline during consumption could be attributed to direct response to the flavour of the novel food, rather than to energy content of the Eaten portion.

If SSS were in any way an expression of FCL or learned satiety, then participants in the high-energy condition were predicted to develop a greater degree of pleasantness decline during the post-conditioning SSS tests than in the first baseline SSS test. In addition, it was predicted that the HED condition would demonstrate greater SSS than the low-energy condition post-conditioning.

5.2.2. Exp. 5 Method

5.2.2.1. Exp. 5 Design

The experiment used a mixed design, contrasting changes in pleasantness ratings of three snack foods (the Eaten test food, an Uneaten savoury contrasting food and an Uneaten sweet contrasting food) on three separate test days: at baseline, after four exposures to a version of the Eaten food, and after eight exposures to a version of the Eaten food. These within-subject contrasts of effects of exposure were combined with differences in energy density of the test food consumed during the eight exposure sessions, with different groups of participants consuming either a High- or Low-energy density version of the Eaten test food.

5.2.2.2. Exp. 5 Participants

Inclusion and exclusion criteria for recruitment are detailed in (see Section 2.3: Participant Selection). Twenty-six men and Twenty-six women were recruited and randomly assigned to one of two exposure-snack conditions, giving 26 participants in each condition (13 men and 13 women). Data from one male participant was excluded from the analyses as the individual demonstrated unreliable attendance and time-keeping patterns which may have rendered the resulting data unreliable. The remaining 51 participants' ages ranged from 19 to 33 years old (mean 22.2 ± 0.5). BMI ranged from 17.8 to 30.6 kg/m² (mean 22.3 ± 0.4). TFEQ-R scores ranged from 0 to 6 (mean 3.1 ± 0.3) and self-reported average daily caffeine intake from 0 to 195 mg (mean 72.4 ± 9.0). Neither age ($F(1, 49)=0.85$, $p=.361$), BMI ($F(1, 48)=1.74$, $p=.679$), TFEQ-R scores ($F(1, 49)=0.00$, $p=.951$) nor average caffeine intake ($F(1, 49)=0.73$, $p=.398$) differed significantly between the two conditions.

5.2.2.3. Exp. 5 Foods

Extensive benchwork was conducted with the aim of creating high-energy density and low-energy density versions of the same snack food that would be novel and moderately pleasant (to minimise ceiling and floor effects).

Pilot testing was carried out at each stage of development to ensure that the foods were matched in flavour and texture as closely as possible. Four foods (two high-energy density, two low-energy density) were tested in the final pilot, the results of which are

reported here. Thirteen participants (10 women and 3 men) were presented with 10g portions of four variations of the snack in individual 50 ml clear plastic containers labeled with a letter and ordered alphabetically on a tray. Unbeknown to the participants, snacks A and D were low-energy and snacks B and C were high-energy. Sensory and hedonic evaluations were completed using 100 mm pre-printed VAS (see Appendix K).

Participants rated each sample on the following properties: sweet; bitter; creamy; pleasant; and novel (to ensure prior learning did not interfere with pleasantness ratings). Participants were then asked to select one snack from those labeled A or D, and one from those labeled B or C as the pair they thought were best matched in flavour and texture.

Single-sample t-tests were conducted on pleasantness ratings, with 50 as the test value, as this was the mid-point of the possible ratings from 0 to 100. Results for pleasantness and novelty ratings are shown in Table 5.1. In accordance with the food selection in previous experiments (see Sections 3.1.2.3: Exp. 1 Foods and 4.2.2.3: Exp. 2 Foods), novelty ratings were not statistically tested, as any rating above zero implies that the snack bar was novel in some way. In addition to this, mean novelty ratings for each piloted snack were all above the mid-point of 50.

Table 5.1: Mean pleasantness and novelty ratings for each snack tested in the pilot study for Experiment 5. Snacks in bold type were selected for inclusion in the main Experiment.

Snack Version	Pleasantness rating	Novelty rating
A Low-energy	56.7 (\pm 6.7)	53.7 (\pm 5.7)
B High-energy	35.2 (\pm 8.3)	67.3 (\pm 6.1)
C Low-energy	39.2 (\pm 5.8)	61.6 (\pm 4.1)
D High-energy	54.5 (\pm 5.5)	64.9 (\pm 4.9)

* Indicates a pleasantness rating greater than the test value of 50 ($p < .05$).

Nine of the thirteen participants selected the snack versions labeled A and B as the best matched pair. Three participants selected the combination D and C; and one selected A and C. The results of this final pilot test indicated that versions A and B were rated by participants to be the best matched pair of low- and high-energy samples, and as both of these snack foods met the criteria of moderate pleasantness and novelty, they were selected for the experiment

The resulting experimental test foods were produced in-house from proprietary ingredients, and were sweet, homogenous snacks that resembled a pink blancmange, yet were slightly firmer and more jelly-like in texture. The foods comprised a combination of

a proprietary sugar-free lemon & lime jelly powder (Hartley's brand); strawberry flavoured powdered blancmange mixture (Angel Delight "No Added Sugar" brand, Premier Ambient Products UK Ltd, Lincs); semi-skimmed milk; water; and the flavours "coconut" and "cream" (IFF). Energy density was manipulated by the addition of an 84 % instantised whey protein isolate, (AlacenTM 450) and maltodextrin (Complex-Carbs, Garnell Nutrition) to the high-energy version. Ingredients for both versions of the food are shown in Table 5.2. Evidence suggests that protein is more satiating than carbohydrates (see Section 1.2.2.3), but as protein is more readily detected in foods (by an increase in 'graininess' of the texture), the energy density differences were generated with a compromise of 50% instantised whey protein, and 50% carbohydrates. Instantised whey protein dissolves more efficiently, which helped to conceal texture differences in the foods, and the inclusion of protein maximised the effect of the energy differences between the two versions of the test food.

Table 5.2: Ingredients per 200g portion of the high- and low-energy density test food in Experiment 5

Units	Ingredients per 200g portion	Test food version	
		Low-energy density	High-energy density
g	Milk	86.0	75.0
drop	Cream flavour	1.0	1.0
drop	Coconut flavour	1.0	1.0
g	Angel Delight	13.0	12.0
g	Jelly Powder	4.0	3.0
g	Boiling water	65.0	63.0
g	Cold water	50.0	12.0
g	Protein	N / A	20.0
g	Maltodextrin	N / A	21.0

Both final versions of the exposure snack food (one high-energy density, one low-energy density) were made in the same way. The flavourings were added to the cold milk in the mixing bowl of a food processor set to a low speed, and the Angel Delight was then slowly added until all the powder dissolved into the milk and the texture started to thicken. With the high-energy density version, the powdered protein and then maltodextrin were then added until fully incorporated and the mixture became smooth. Meanwhile, the jelly granules were dissolved in boiling water and this mixture added, followed by the remaining cold water. The mixture was then divided into the required portions (50g for SSS testing, 200g for exposure portions), and were refrigerated to solidify. Macronutrient and energy content for the foods are shown in Table 5.3.

Table 5.3: Macronutrient and energy composition of the high- and low-energy versions of the test snack food selected for Experiment 5.

Snack version	Per 100 g		Per 200 g portion	
	Low-energy	High-energy	Low-energy	High-energy
CHO (g)	10.9	31.6	21.9	62.2
Protein (g)	5.0	20.5	9.9	41.0
Fat (g)	4.4	5.8	8.8	11.5
Energy (kcal)	102.8	258.4	205.6	516.7

In all tests for SSS, 50 g of the low-energy snack was presented as the eaten food. The uneaten foods were two sensorially different snacks selected from previous experiments as they met the criteria of moderately pleasant (to minimise ceiling and floor effects) and novel (to ensure prior learning did not interfere with pleasantness ratings): the selected sweet contrast was Sainsbury's vanilla marshmallows and the savoury contrast was Beef Teriyaki Crackers (Walkers Sensations brand). Energy and macronutrient content of the uneaten foods are shown in Table 5.4.

Table 5.4 Macronutrient and energy composition of the Uneaten foods in Experiment 5.

	Per 100 g	
	Cracker	Marshmallow
CHO (g)	62.0	78.5
Protein (g)	1.4	4.1
Fat (g)	26.0	0.0
Energy (kcal)	490.0	330.0

5.2.2.4. Exp. 5 Rating scales

In all three SSS tests, all ratings were taken using electronic VAS with SIPM software (see Section 2.4). Ratings were taken for appetite ('hungry', 'full' and 'thirsty'), hedonics ('pleasant') and sensory attributes ('novel', 'sweet', 'sour', 'savoury', and 'bitter') of the foods. For this study an additional hedonic rating was introduced: 'desire to eat more of this'. Mood ratings were taken ('lethargic', 'alert', 'relaxed' and 'tense'), but as these served only as distractors, these ratings were not analysed.

In each of the eight exposure sessions, participants completed ratings on printed 100mm VAS forms (see Appendix L). The 'not at all' anchor always appeared on the left, and the 'extremely' anchor on the right of the scale. The VAS were set out on four sheets of A4 paper, which discouraged participants from referring back to previous responses. Mood, appetite, sensory and hedonic ratings were the same as those presented in the SSS testing sessions, except that the evaluation of 'savoury' was omitted, as the exposure stimuli were both sweet and this rating was irrelevant.

5.2.2.5. Exp. 5 Procedure

Each participant attended the laboratory on 11 non-consecutive days, with an upper limit of 14 days between appointments. Participants fasted from 23:00h on the night before laboratory sessions, consuming nothing but water until arrival at the laboratory, at which point the controlled breakfast was provided (see Section 2.4.2: Laboratory Breakfasts). After breakfast, participants were free to leave the laboratory, but continued fasting (water was allowed) until they returned for testing, which took place three hours after the breakfast appointment, in a snack context. Fasting between breakfast and laboratory sessions was increased to three hours for this experiment, from two hours as used in Experiments 1, 2, 3, and 4. The current study aimed to induce dietary learning, and there is much evidence that such learning is facilitated by motivational state (see Section 1.3.3: Dietary Learning). To this end, the three-hour post-breakfast fast was expected to induce moderate hunger.

On the first, sixth and final test days, participants completed the SSS testing paradigm (see Section 2.1: Methodology and Measurement of SSS in the Literature). Mood, appetite, sensory and hedonic ratings were completed by electronic VAS administered by SIPM software (see Section 2.4.1: Laboratory Setup), and testing was carried out in accordance with the standard SSS testing procedure (see Section 2.5: General Procedure). Samples of three test foods were presented in the pre-consumption and post-consumption phases of SSS testing: the test food (a sweet semi-solid homogenous dessert, always presented as Food A); savoury oriental cracker (always presented as Food B); and marshmallow (always presented as Food C). Foods were not counterbalanced in SSS testing. The aim of the experiment was to ascertain if dietary learning (induced by pairing the CS flavour of the desert snack with a UCS of high-energy content) would modulate the magnitude of SSS experienced when consuming the low-energy version of the CS-flavoured desert snack post-exposure. As such, during the consumption phase of SSS testing, 50g (see Section 2.5: General Procedure) of the low-energy version of the exposure snack was presented (as the Eaten food). The cracker and marshmallow (Uneaten foods) were presented at room temperature, and the low-energy Eaten food was served from a refrigerator maintained at $<5^{\circ}\text{C}$.

On the remaining eight test days, participants completed an exposure session and consumed a 200 g fixed portion of either the low-energy or high-energy version of the test snack, depending on allocation to experimental condition. Exposure sessions took

place in one of four open testing booths. The booths are separated by screens that prevent seated participants from seeing stimuli or response sheets in other booths. Mood, appetite, sensory and hedonic ratings were completed by hand on pre-printed 100 mm VAS forms (see Appendix L). All instructions were provided on the VAS forms. Initially participants completed a page of ratings for mood and appetite, after which they were instructed to call the experimenter. The experimenter then provided the exposure food in a 300 ml white ceramic dish, presented on a white plastic tray (28.3 x 21.4 cm) along with a spoon and a napkin, and asked participants to turn the page. The second page instructed participants to taste the exposure food and rate it on sensory and hedonic scales. Instructions specified that participants then finish the portion of food. After the food was consumed, another page repeated the mood and appetite ratings, after which participants were once again instructed to call the experimenter. The experimenter removed the three pages of completed ratings from the response pack, and returned the fourth page to the participant. Participants were then free to leave the laboratory, and instructed to consume nothing but water for one hour, after which they completed the final VAS sheet of repeated mood and appetite ratings. Participants were then free of consumption restrictions, and returned the final VAS sheet upon their next appointment with the experimenter.

At the end of the final test session, participants were asked to complete a written structured debrief (see Appendix M). Firstly, participants were asked "In your own words, please write one or two sentences on what you think this experiment was about" and space was provided for the response. They then turned the page to reveal three questions. They were asked to respond 'yes' or 'no' to question 1: "Do you think there was any difference between the pink snacks you ate on "computer" test days, and "pen & paper" test days?". This was followed by question 2: "How certain are you?", and a 100 mm VAS was provided for the response. One end of the scale was anchored with "Not at all certain" and the other with "Extremely certain". Finally, participants were asked question 3: "If you answered "Yes" to Q1, what do you think was different?". Again, space was provided for a written response.

5.2.3. Exp. 5 Results

5.2.3.1. Exp. 5 Initial Pleasantness and Novelty Ratings

As with previous experiments, the snacks used during SSS testing had been selected and developed to ensure they were moderately pleasant and novel to some degree. The snacks were not counterbalanced as Eaten and Uneaten foods in SSS testing (see Section 5.2.2.5: Exp. 5 Procedure): the Eaten food was always the low-energy version of the test food, and the Uneaten foods were always the cracker (savoury) and the marshmallow (sweet). Therefore it was imperative to test the assumptions made about the foods by analysing initial ratings of pleasantness and novelty (made upon first contact with the foods during the pre-consumption phase of the first SSS test on day 1).

A mixed ANOVA was conducted on initial pleasantness ratings with Food as the within-subject factor (Eaten test food, Uneaten cracker, Uneaten marshmallow), and Exposure Condition (Low-energy density, High-energy density) as the between subject factor. As can be seen in Figure 5.1, the Eaten test food received lower pleasantness ratings than the two Uneaten foods. This is supported by a significant main effect of Food ($F(2,98)=7.26$, $p=.001$). The main effect of Experimental Condition was non-significant ($F(1, 49)=1.60$, $p=.212$), indicating that at baseline, pleasantness ratings for the foods did not differ significantly between the Conditions. This was to be expected, as at baseline there were no treatment differences between the groups. Initial pleasantness ratings did not differ between foods as a function of experimental condition, as indicated by a non-significant interaction of Food x Experimental condition ($F(2, 98)=0.64$, $p=.528$).

Pairwise comparisons of rated pleasantness among the foods revealed that across both conditions, the Eaten test food was rated significantly less pleasant than each of the Uneaten foods (Uneaten cracker $p=.001$; Uneaten marshmallow $p=.044$), but that the Uneaten foods were rated similarly ($p=1$).

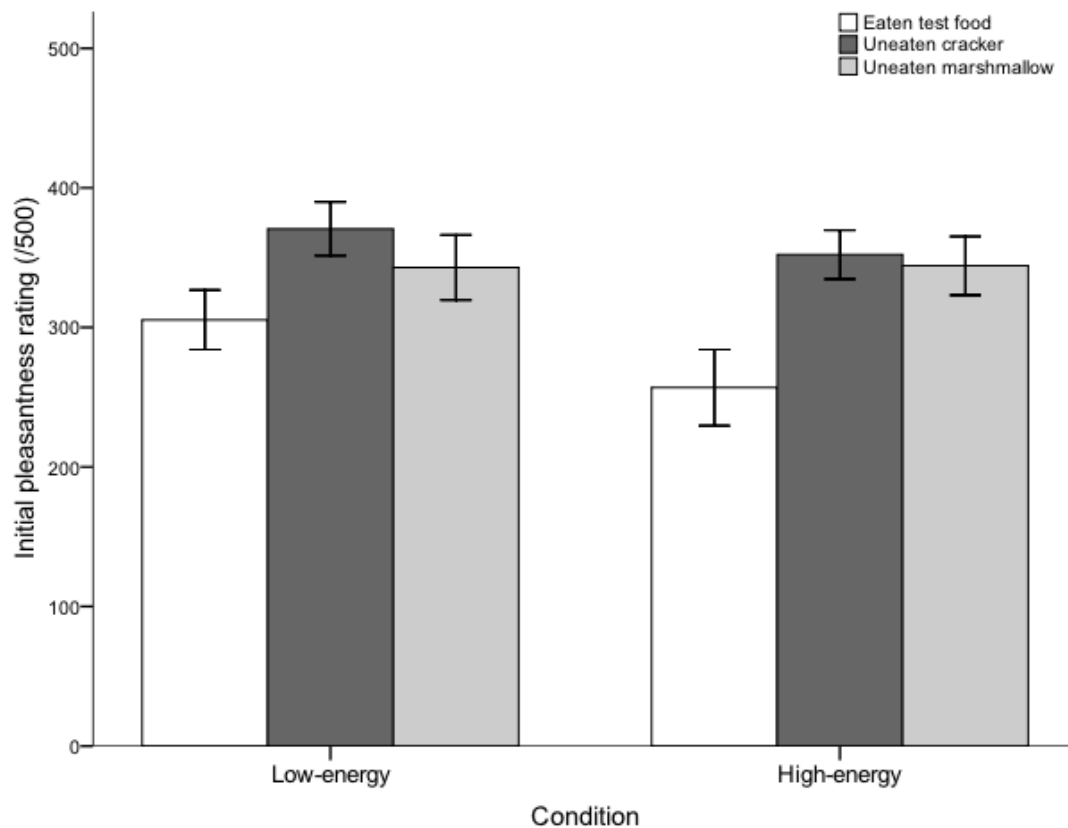


Figure 5.1: Initial pleasantness ratings for each food by experimental condition in Experiment 5.

Initial novelty ratings were also analysed with mixed ANOVA, with Food as the within-subject factor (Eaten test food, Uneaten cracker, Uneaten marshmallow), and Exposure Condition (Low-energy density, High-energy density) as the between subject factor. As can be seen in Figure 5.2, the Eaten test food was rated more novel than the two Uneaten foods. This is supported by a significant main effect of Food ($F(2,98)=10.62$, $p=.000$). The main effect of Experimental Condition was non-significant ($F(1, 49)=0.53$, $p=.470$), indicating that at baseline, novelty ratings for the foods did not differ significantly between the Conditions. This was to be expected, as at baseline there were no treatment differences between the groups. Initial novelty ratings did not differ between foods as a function of experimental condition, as indicated by a non-significant interaction of Food x Experimental condition ($F(2, 98)=0.06$, $p=.945$).

Pairwise comparisons of novelty ratings among the foods revealed that across both conditions, the Eaten test food was rated significantly more novel than each of the Uneaten foods (Uneaten cracker $p=.001$, Uneaten marshmallow $p=.001$), but that the Uneaten foods were rated similarly for novelty ($p=1$).

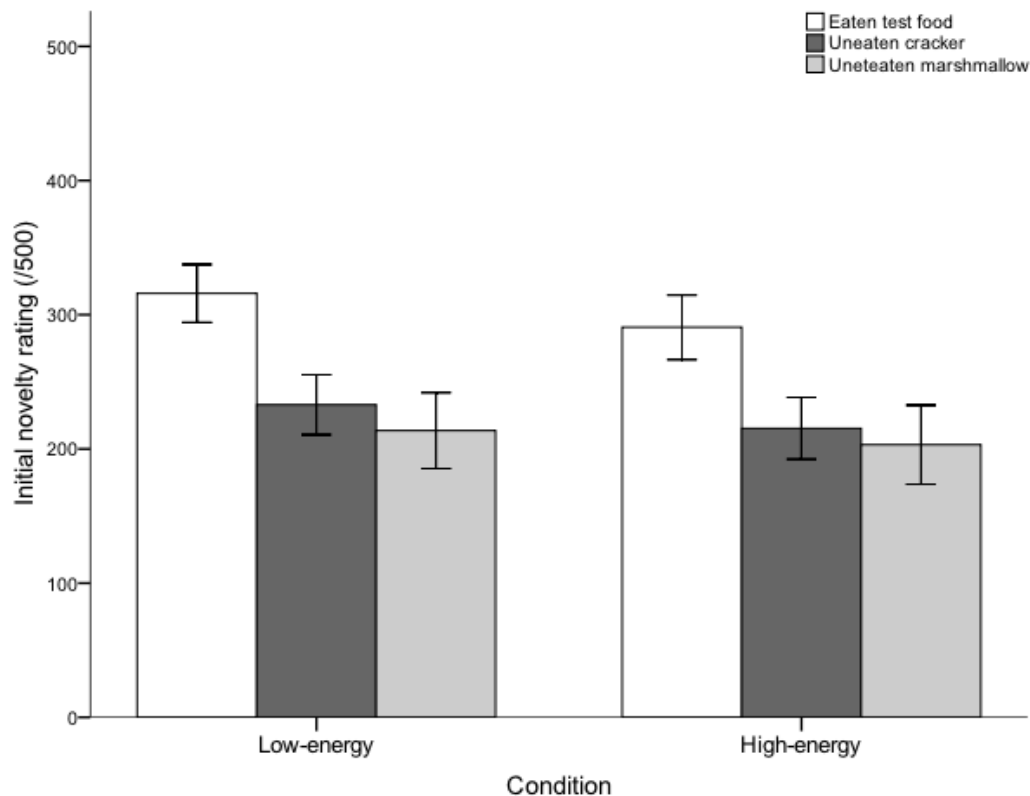


Figure 5.2: Initial novelty ratings for each food by experimental condition in Experiment 5.

That the Eaten test food was rated significantly less pleasant yet more novel than both the Uneaten foods (cracker and marshmallow) might have given rise to cautious interpretation of further results. However, none of the mean ratings for pleasantness or novelty for each of the three foods were particularly low or high - each was well within the extremes possible on the zero to 500 point scale, allowing scope for adjustment of these ratings during the course of the experiment.

5.2.3.2. Exp. 5 Sensory-Specific Satiety

In order to assess SSS, a separate ANOVA was conducted for each of the three test days, on Change In Pleasantness, with Food as the within-subject factor (Eaten, Uneaten Cracker, Uneaten Marshmallow), and Exposure Condition as the between subject factor (LED, HED).

SSS Test Day 1

Change In Pleasantness data for Test Day 1 are shown in Figure 5.3. The main effect of Food was significant ($F(2, 98)=12.47, p<.000$), with pairwise comparisons revealing that across the all conditions, the Eaten food showed a greater decline in pleasantness ratings to the Uneaten Cracker ($p=.001$), indicating SSS. Change In Pleasantness ratings for the

Uneaten Marshmallow however, were not significantly different to that of the Eaten food ($p=1.00$), and as both these foods were sweet, this can be interpreted as a transfer effect. This interpretation is supported by the fact that the Uneaten Marshmallow declined in pleasantness to a significantly greater degree than the Uneaten Cracker ($p=.001$).

On the first SSS test day, at baseline, there were no treatment differences between groups, and as expected, the main effect of Exposure Condition was not statistically significant ($F(1, 49)=1.62, p=.209$). Against expectations the magnitude of decline in rated pleasantness for the LED condition was slightly greater than in the HED condition, though this difference was not statistically significant. The interaction between Food and Exposure Condition also failed to reach significance ($F(2, 98)=2.05, p=.135$), indicating that the effect of Food was similar between conditions.

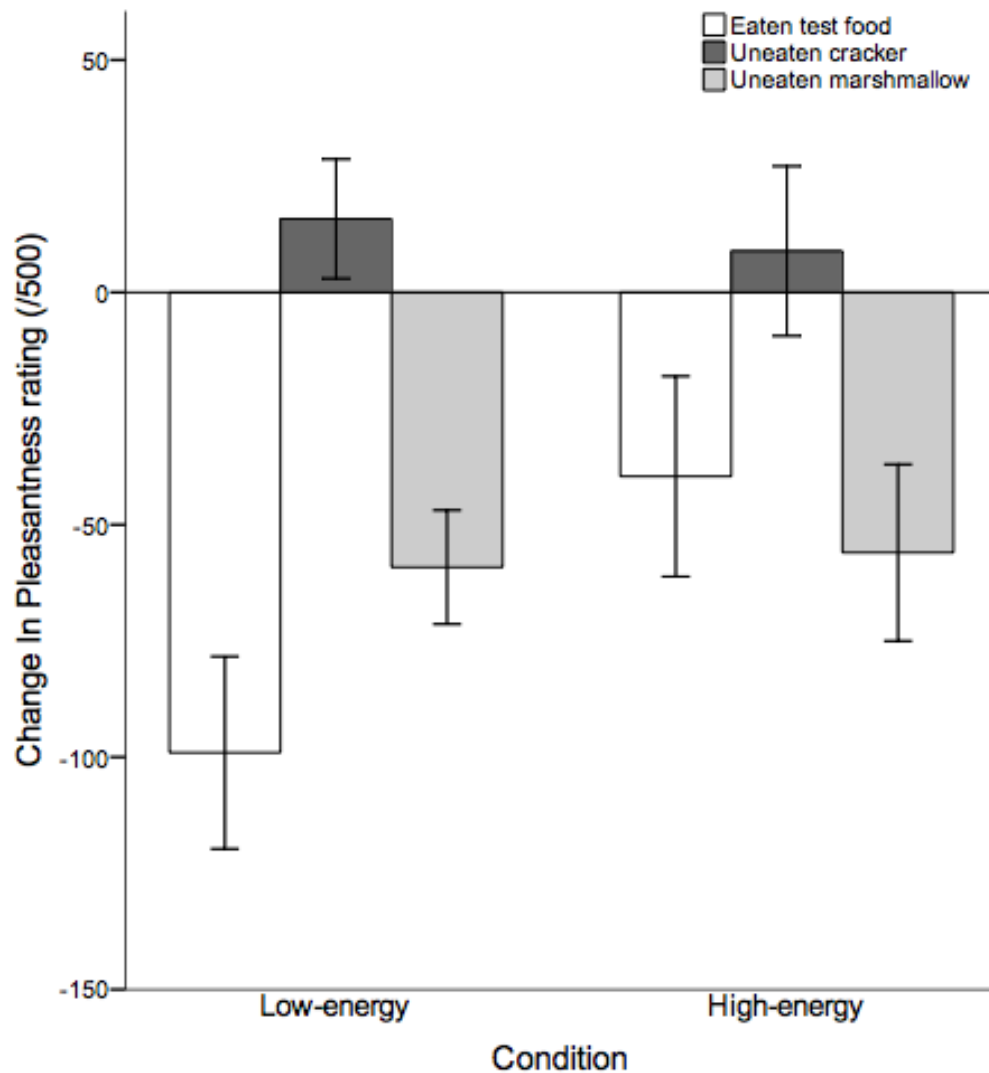


Figure 5.3: Change In Pleasantness ratings for each food in each exposure condition on SSS Test Day 1 in Experiment 5.

SSS Test Day 2

On SSS Test Day 2 (data shown in Figure 5.4), neither the main effect of Food ($F(2, 98)=2.58$, $p=.081$), nor that of Exposure Condition ($F(1, 49)=3.45$, $p=.070$) were statistically significant, indicating that Change In Pleasantness was similar across all three Foods and Exposure Conditions. Furthermore, any differences in Change In Pleasantness between the foods did not differ significantly between Conditions (non-significant interaction between Food and Exposure Condition ($F(2, 98)=2.79$, $p=.066$)). Thus, after four exposures to either the LED or HED test food, Change In Pleasantness during SSS testing reduced in magnitude against baseline for all foods, especially the Eaten food. Curiously, the decline in pleasantness for the Uneaten Marshmallow in the HED Exposure Condition remained very similar to that on Test Day 1.

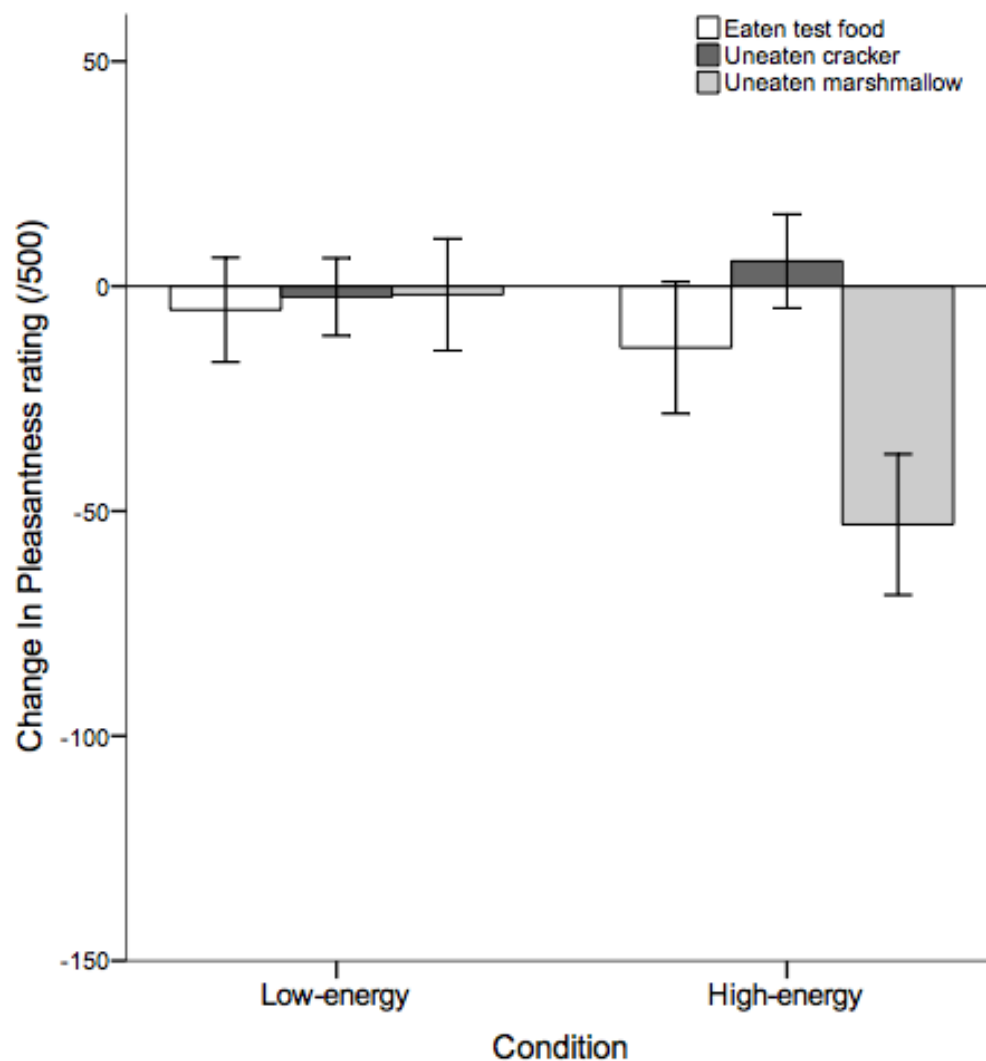


Figure 5.4: Change In Pleasantness ratings for each food in each exposure condition on SSS Test Day 2 in Experiment 5.

SSS Test Day 3

Test Day 3 occurred after eight exposures to either the LED or HED Exposure food, and data for Change in Pleasantness during SSS testing is shown in Figure 5.5. Once again the results indicate an absence of SSS and differences between conditions, with non-significant main effects of Food ($F(2, 98)=0.03, p=.970$) and Exposure Condition ($F(1, 49)=1.78, p=.188$), and non-significant interaction between them ($F(2, 98)=2.10, p=.126$).

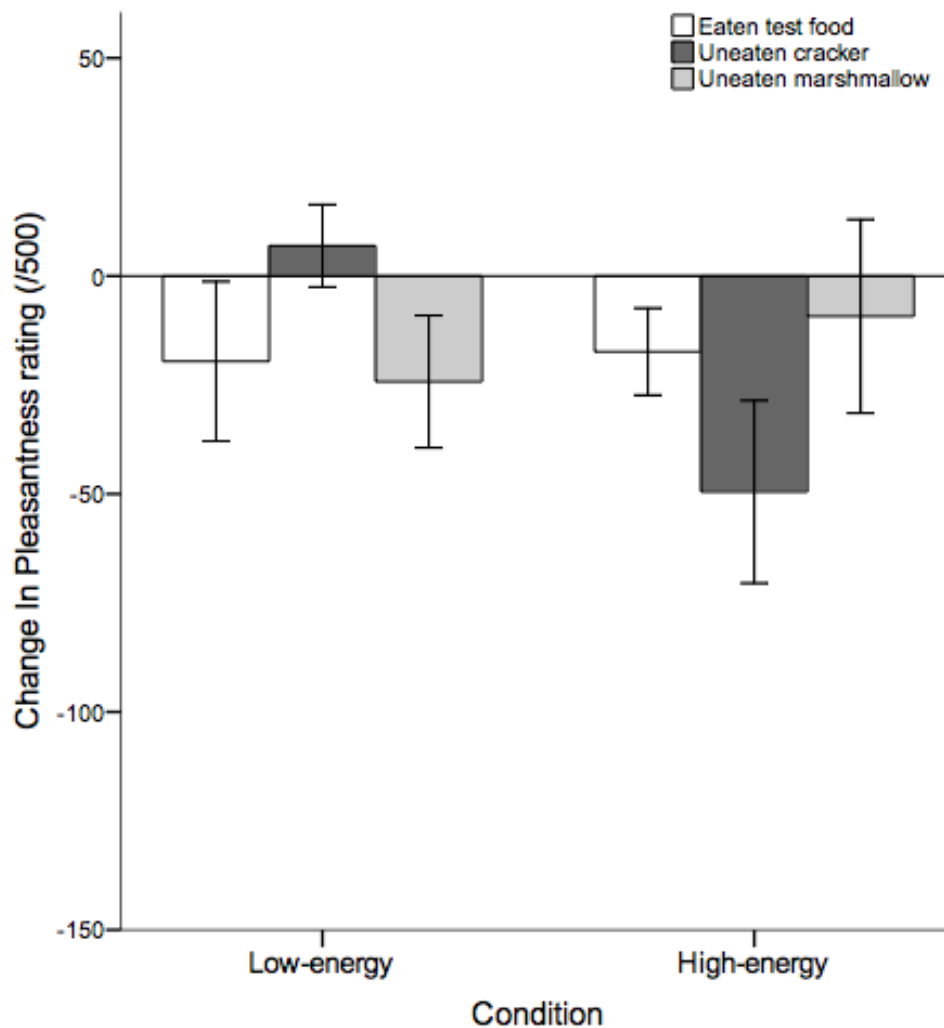


Figure 5.5: Change In Pleasantness ratings for each food in each exposure condition on SSS Test Day 3 in Experiment 5.

5.2.3.3. Exp. 5 Change in Hedonic Ratings Across SSS Test Days

In order to establish whether exposure to either the LED or HED food altered the changes in hedonic ratings to the LED test food, a mixed ANOVA was conducted on Change In Pleasantness ratings for the Eaten food, with SSS Test Day (1, 2, 3) as the within-subject factor, and Exposure Condition (LED, HED) as the between-subject factor (data shown in Figure 5.6). Change In Pleasantness ratings between Test Days failed to meet the assumption of Sphericity (Mauchly's $W(2)=.80, p=.004$) so the Greenhouse-Geisser

adjusted statistics are reported for the within-subject factor. The main effect of Test Day was statistically significant ($F(1.66, 81.19)=7.71, p=.002$), with the magnitude of the decline in pleasantness for the eaten food being greater on the first test day compared to the second ($p=.003$) and third ($p=.031$). Change in Pleasantness ratings were similar between test days two and three ($p=1$). Both the main effect of Exposure Condition ($F(1,49)=1.57, p=.216$) and interaction between Test Day and Exposure Condition ($F(1.66, 81.19)=2.46, p=.101$) failed to reach significance, indicating that Change in Pleasantness ratings did not differ between Exposure Conditions, and did not differ between Exposure Conditions across the Test Days.

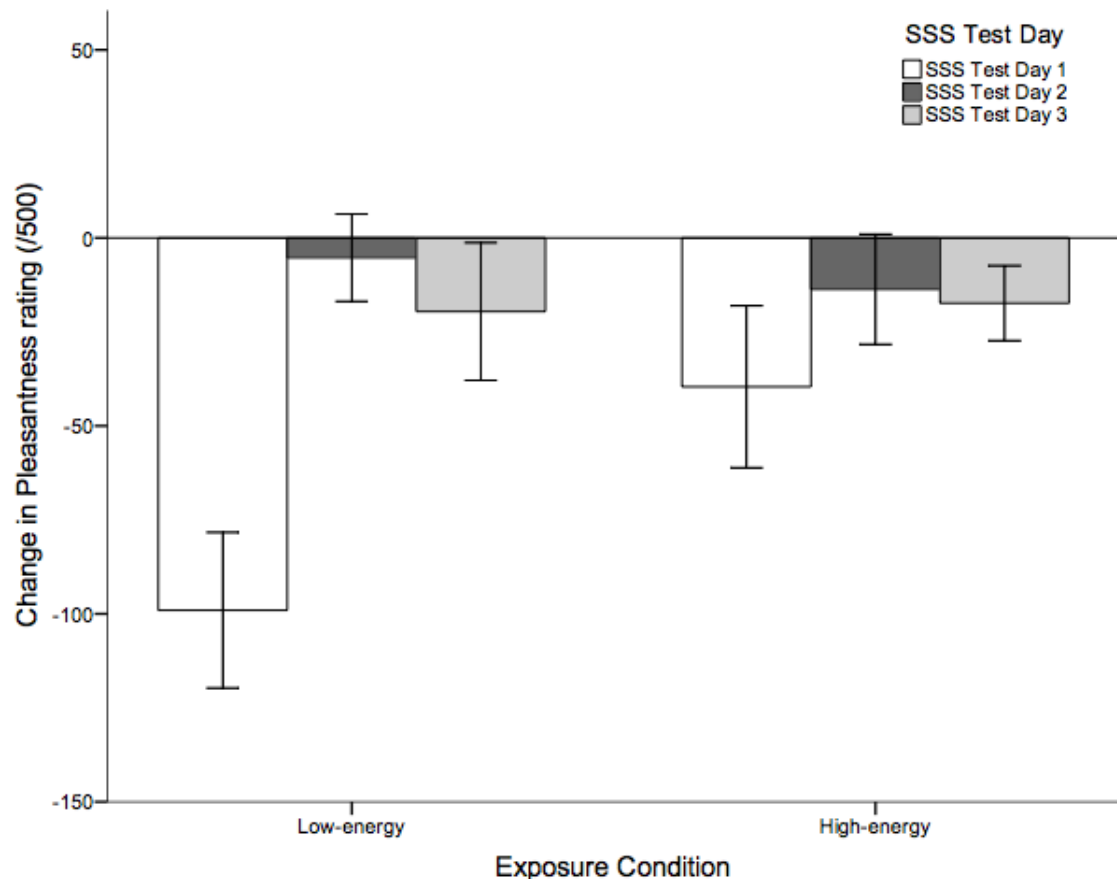


Figure 5.6: Change In Pleasantness ratings for the Eaten food on each SSS Test Day for each exposure condition in Experiment 5.

As ratings of Desire to Eat More are closely related to Pleasantness, the ANOVA was repeated, this time conducted on Change In Desire To Eat More of the Eaten food, with Test Day as the within-subject factor and Exposure Condition as the between-subject factor (data shown in Figure 5.7). The data show a similar pattern to that of Change In Pleasantness ratings, with a greater magnitude of Change In Desire To Eat More on the first test day than the second ($p=.034$) or third ($p=.027$) (main effect of Food $F(2, 98)=4.89, p=.009$), with change ratings being similar between test days two and three

($p=1$). Change in Desire To Eat More did not differ between Exposure Conditions ($F(1, 49)=0.71$, $p=.403$), nor did the ratings between conditions differ between test days (interaction: Test Day \times Exposure Condition $F(2, 98)=.24$, $p=.784$).

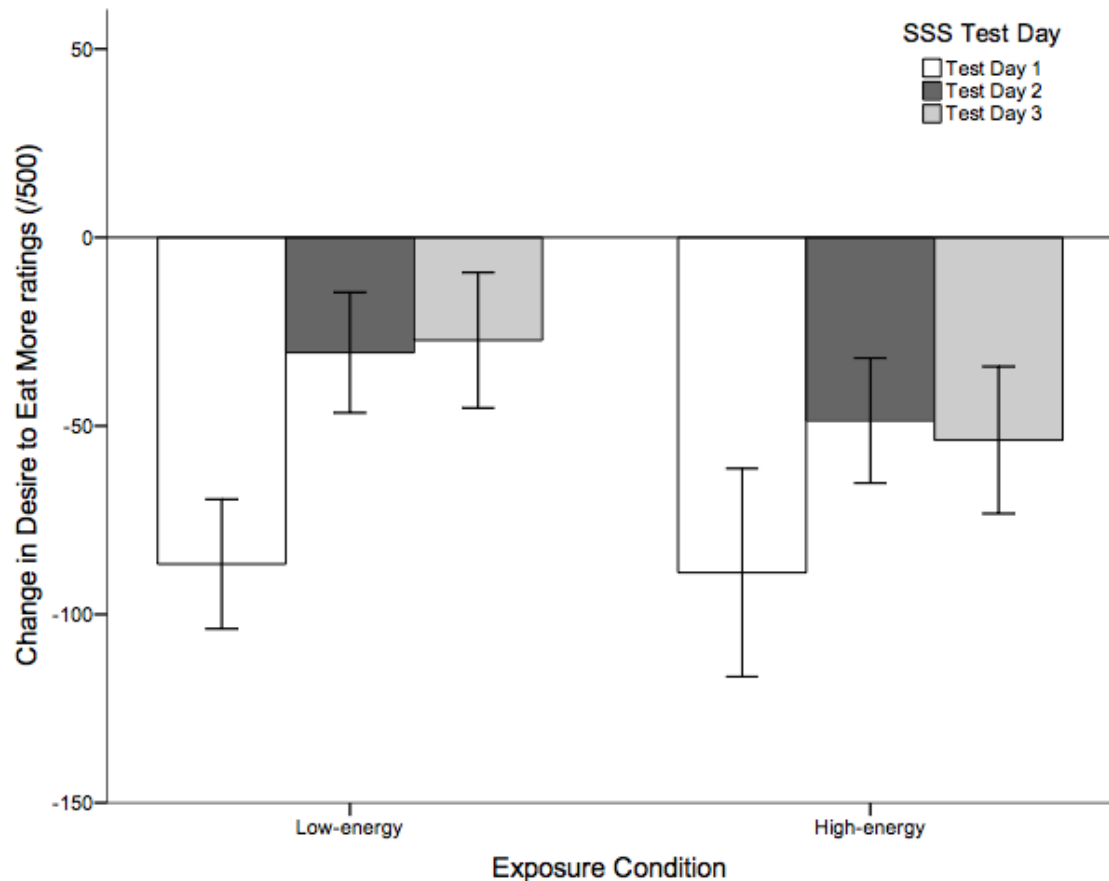


Figure 5.7: Change in Desire To Eat ratings for the Eaten food on each SSS Test Day for each exposure condition in Experiment 5.

Interestingly, the apparent baseline differences between conditions in ratings decline on test day one that were evident for Pleasantness, are not apparent for Desire to Eat More, in which both groups show similar mean ratings at the start of the experiment.

5.2.3.4. Exp. 5 Change in Initial Pleasantness for the Eaten Food Across SSS Test Days

A mixed ANOVA was conducted on initial pleasantness ratings for the Eaten food during the pre-consumption phase of SSS testing, with SSS test day (test day 1; 2; 3) as the within-subject factor, and Exposure Condition (Low-energy; High-energy) as the between-subject factor (data shown in Figure 5.8). Pleasantness ratings between test days failed to meet the assumption of Sphericity (Mauchly's $W(2)=.78$, $p=.002$) so the following statistics are reported with the Greenhouse-Geisser adjustment. The low-energy Eaten food was rated similarly pleasant across test days ($F(1.6, 80.0)=1.46$, $p=.238$) and

between exposure conditions ($F(1, 49)=1.55, p=.220$). The interaction between condition and test day also failed to reach statistical significance ($F(1.6, 80.0)=0.35, p=.665$) indicating that ratings did not differ between conditions as a function of test day.

Thus there was no support for the hypothesis that those exposed to the high-energy version would increase liking more than those in the low-energy condition: overall, pleasantness failed to increase in either condition.

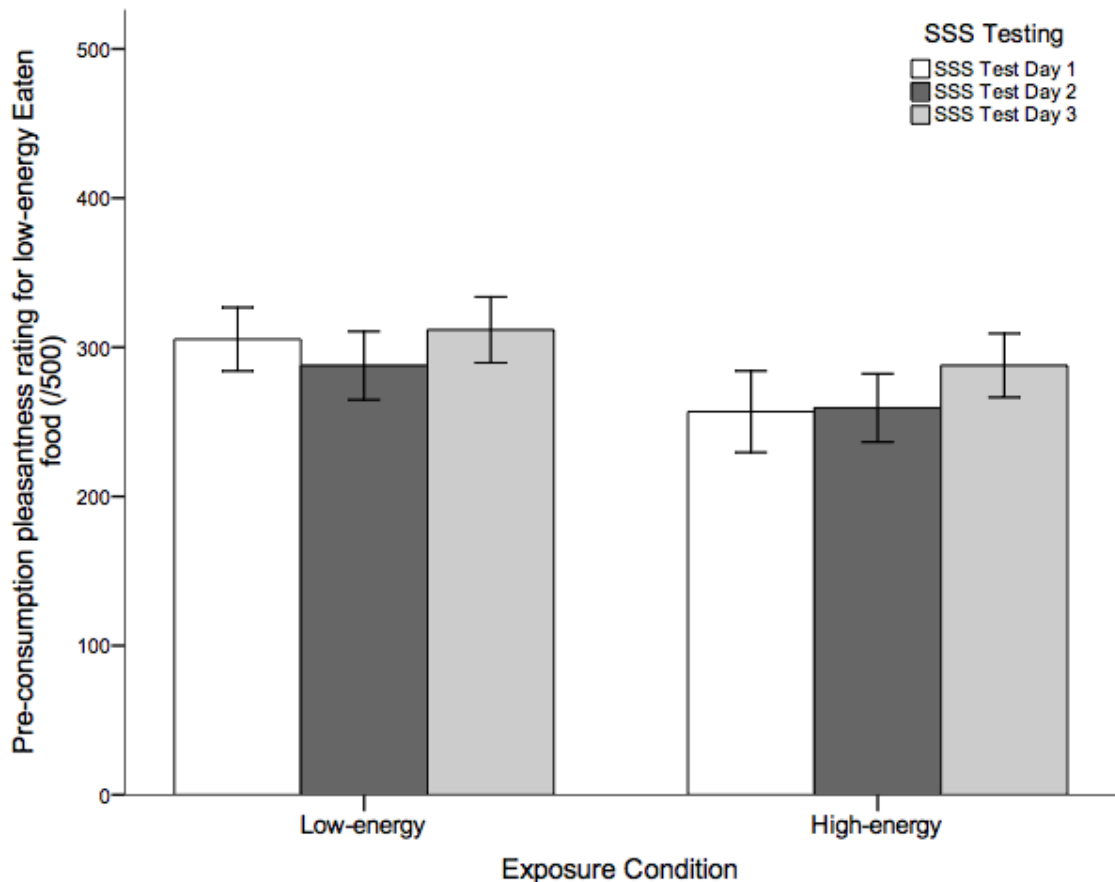


Figure 5.8: Initial pleasantness ratings for the Eaten food for each exposure condition on each SSS Test Day in Experiment 5.

5.2.3.5. Exp. 5 Changes in Initial Novelty for the Eaten Food Across SSS Test Days

A mixed ANOVA was conducted on novelty ratings for the low-energy Eaten food during the pre-consumption phase of SSS testing, with SSS test day (test day 1; 2; 3) as the within-subject factor, and Exposure Condition (Low-energy; High-energy) as the between-subject factor (data shown in Figure 5.9). Novelty ratings for the Eaten food in both Conditions declined with time (significant main effect of Test Day: $F(1.7, 83.3)=16.00, p<.000$), but did not differ significantly between exposure Conditions (main effect of

Condition: $F(1, 49)=3.50$, $p=.068$). The interaction between condition and test day also failed to reach statistical significance ($F(1.70, 83.3)=0.91$, $p=.394$) indicating that novelty ratings did not differ between conditions as a function of test day. Pairwise comparisons of rated novelty between test days revealed that across both conditions, the Eaten food declined in novelty from Test Day 1 to Test Day 2 ($p=.002$), and from Test Day 1 to Test Day 3 ($p<.000$), but novelty did not decline significantly between Test Days 2 and 3 ($p=.094$). Such results indicate that the HED and LED foods are similar - because the HED group also showed a decline in novelty over the course of the exposures, such that matched that of, and did not significantly differ from, the LED group, who had the same food all the time.

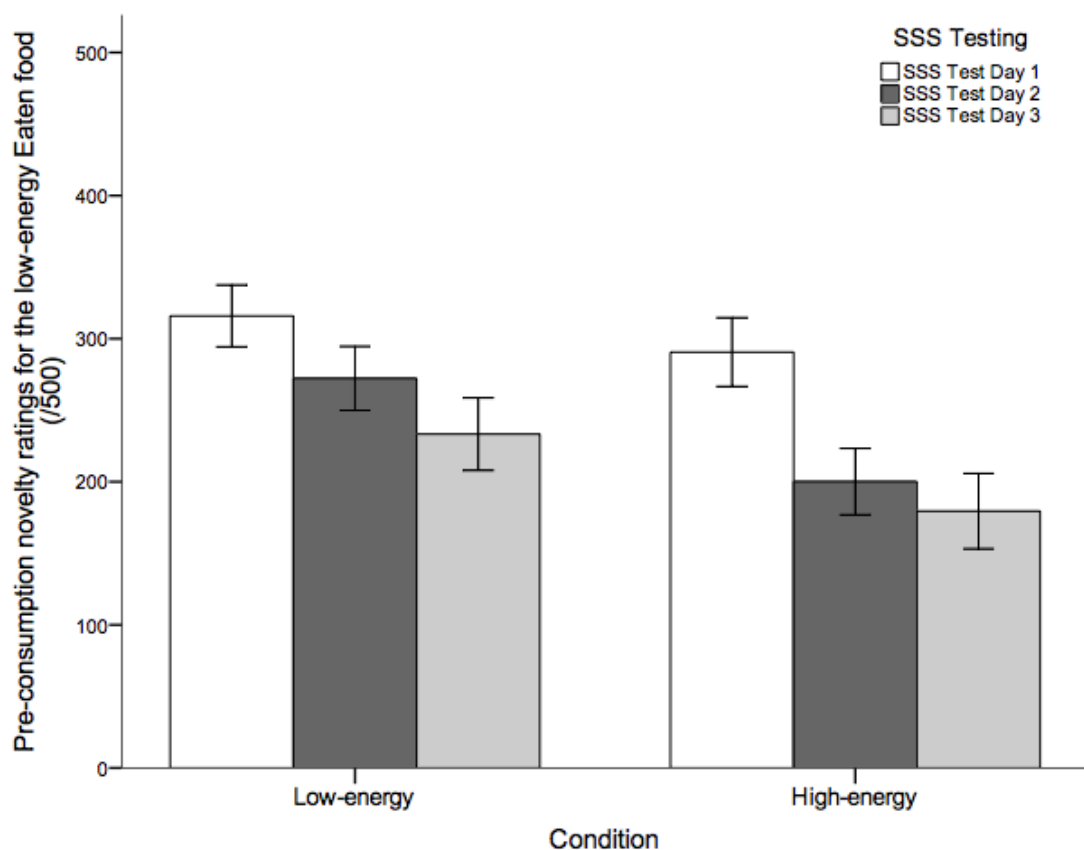


Figure 5.9: Initial novelty ratings for the Eaten food for each exposure condition on each SSS Test Day in Experiment 5.

5.2.3.6. Exp. 5 Hunger Ratings

In order to assess whether repeated exposure led to a progressive increase in the degree to which rated hunger declined when the food was eaten, and whether any such change was greater in the HED than LED condition, three mixed ANOVAs were conducted on hunger ratings: at the start of each exposure session; immediately after consumption in the exposure sessions; and 1-hour after the exposure sessions. In each of these analyses, Exposure Session (1 to 8) was the within-subject factor, and Exposure Condition was the

between-subject factor. In all three analyses, hunger ratings between Exposure sessions failed to meet the assumption of Sphericity (at the start of the session: Mauchly's $W(27)=.25$, $p<.000$; immediately after consumption: Mauchly's $W(27)=.19$, $P<.000$); and 1-hour post-consumption: Mauchly's $W(27)=.32$, $p=.019$), so the following statistics are reported with the Greenhouse-Geisser adjustment, where applicable.

Initial Hunger Ratings

Hunger ratings taken at the start of each exposure session (see Figure 5.10) did differ significantly between sessions (main effect of Exposure Session $F(5.19, 254.12)=3.63$, $p=.003$), though not between Exposure Conditions ($F(1, 49)=0.41$, $p=.524$), and the difference in hunger ratings across sessions did not differ between conditions ($F(5.19, 254.12)=1.78$, $p=.116$). Pairwise comparisons between exposure sessions revealed only one statistically significant result, where ratings were higher on Exposure Session 6 than those of Exposure Session 4 ($p=.022$), and this is likely to be a spurious finding.

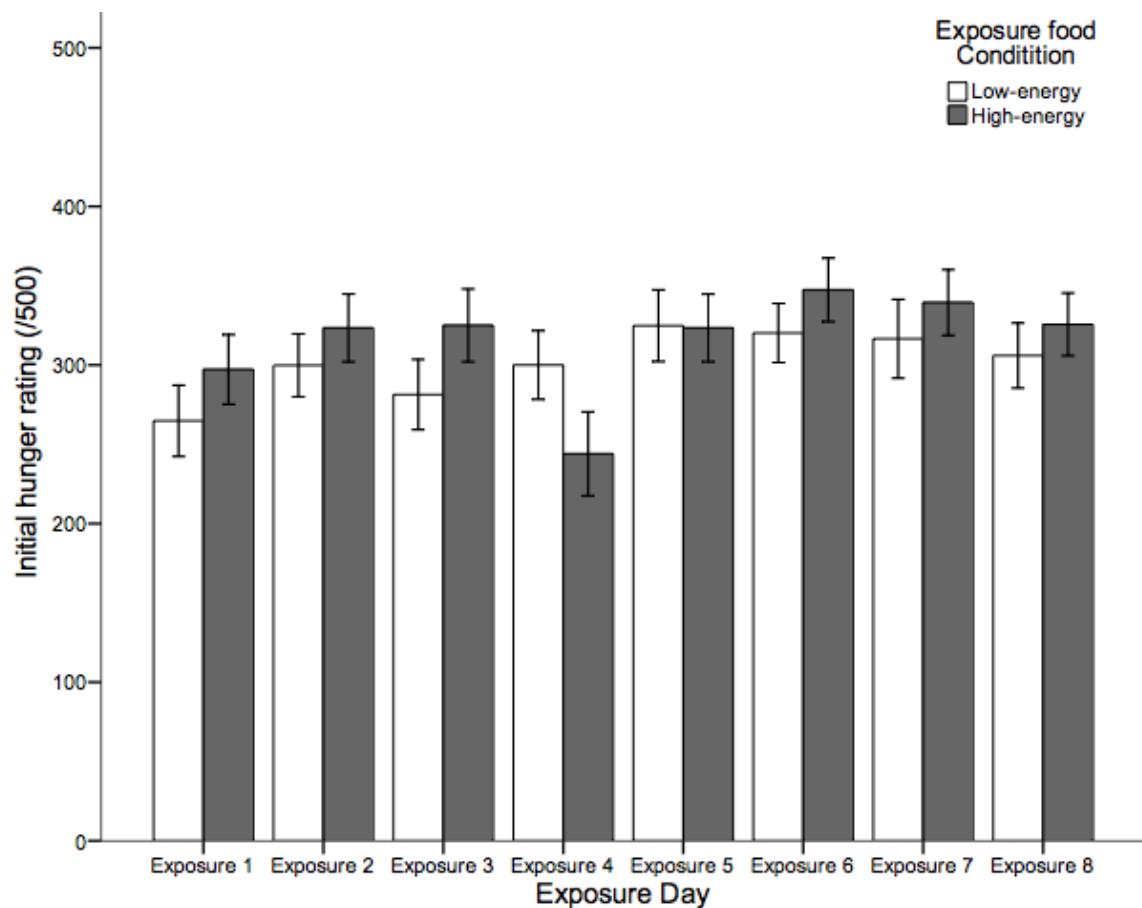


Figure 5.10: Initial hunger ratings for each experimental condition at the start of each exposure session for Experiment 5.

Post-Consumption Hunger Ratings

Hunger ratings taken immediately after consumption of either the HED or LED food at each Exposure Session (see Figure 5.11) also differed significantly between sessions (main effect of Exposure Session $F(4.77, 228.90)=2.32$, $p=.047$), though not between Exposure Conditions ($F(1, 48)=0.54$, $p=.467$), and the difference in hunger ratings across sessions did not differ between conditions ($F(4.77, 228.90)=0.54$, $p=.740$). All pairwise comparisons between exposure sessions were non-significant.

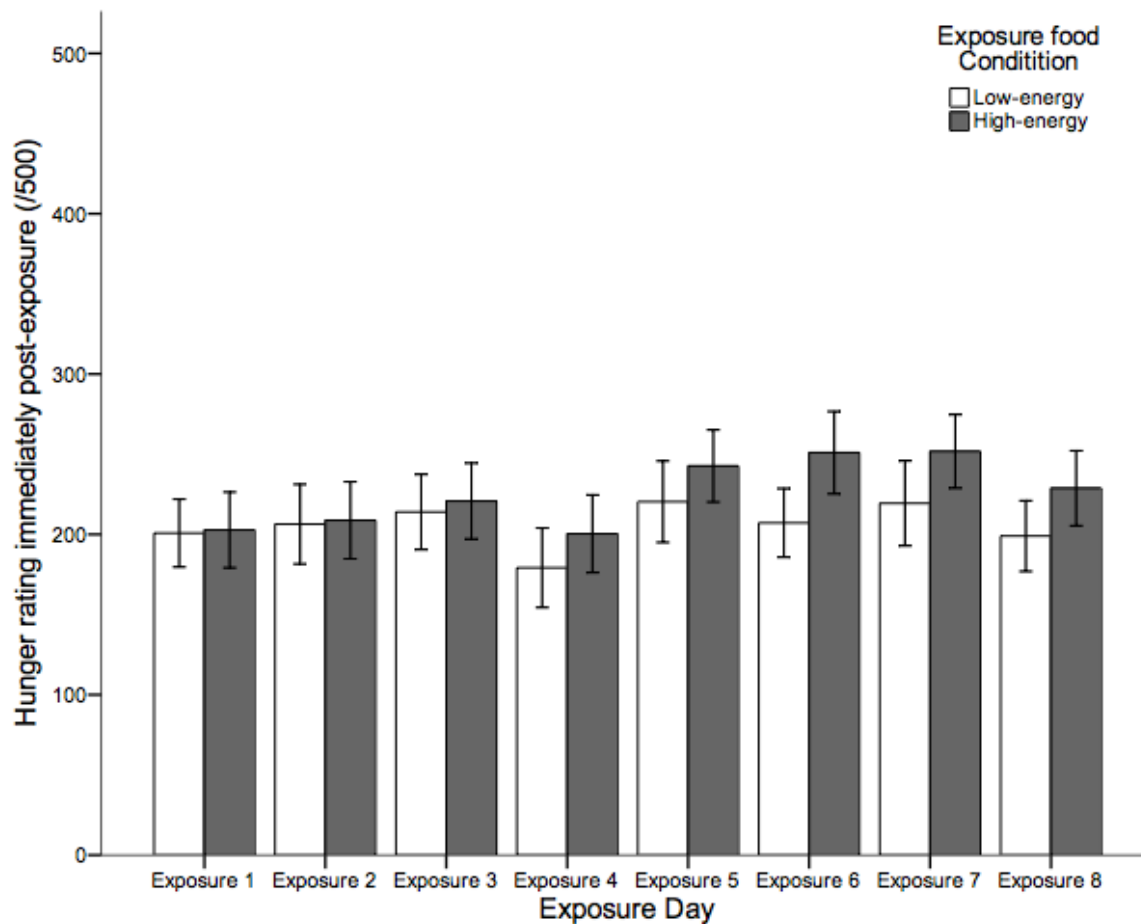


Figure 5.11 Hunger ratings for each experimental condition immediately after each exposure session for Experiment 5.

1-Hour Post-Consumption Hunger Ratings

Hunger ratings taken 1-hour post-consumption at each Exposure Session (see Figure 5.12) did differ significantly between sessions (main effect of Exposure Session $F(5.11, 214.71)=3.42$, $p=.005$), though not between Exposure Conditions ($F(1, 42)=0.00$, $p=.983$), and the difference in hunger ratings across sessions did not differ between conditions ($F(5.11, 214.71)=0.74$, $p=.596$). All pairwise comparisons between exposure sessions were non-significant.

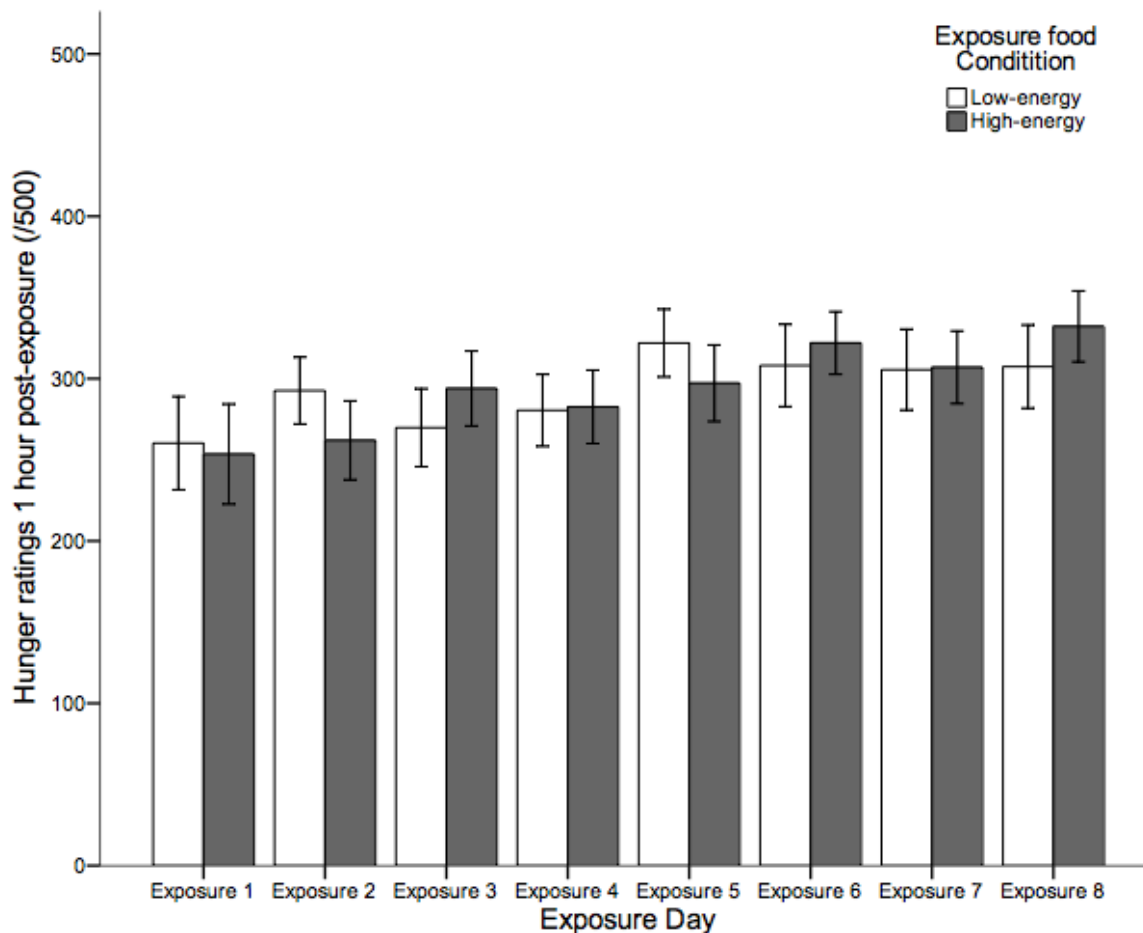


Figure 5.12 Hunger ratings for each experimental condition 1 hour after each exposure session for Experiment 5.

Hunger patterns taken pre-exposure and immediately post-exposure were significantly different across the eight exposure sessions, but there was no clear consistent pattern to these differences. On the other hand, hunger ratings taken 1-hour post-exposure (which also differed significantly across days) showed a general trend to increase during the course of the experiment. However, these ratings did not differ between Exposure condition, nor were the differences across the exposure sessions different between the two conditions. This pattern shows an progressively faster recovery of hunger ratings 1-hour after testing, over the course of the eight exposure sessions. Baseline hunger ratings do not increase over this time, so these results imply that neither version of the exposure food was adequately satiating. This suggests that the differences in energy density between the two versions of the test food were insufficient to differentiate them as low- and high- energy, and leaves the possibility that both foods were similar, and could be regarded as low-energy.

5.2.3.7. Exp. 5 Debriefing

Participants' beliefs about the purpose of the experiment were classified as follows: the effect of food on mood (41%); the effect of sugar or sweetness on mood (8%); the interaction between appetite and mood (24%); investigation into taste perception (8%); and no answer (6%). Two belief classifications were regarded as being close to the actual purpose of the study: the relationship between novelty and liking of food (4%), and how liking changes over time (10%). While the responses in these two classifications related to some aspects of the experimental objectives, no participants guessed at any form of learning, sensory-specific satiety, or energy differences, and as such all participants were deemed suitably naive of the exact aims of the study.

When asked if there was a difference between the pink snacks served on computer test days (SSS testing) and pen and paper test days (Exposure sessions), 58% of participants in the LED exposure condition correctly guessed that the snacks were the same. In the HED exposure condition, 76% of participants correctly guessed that for them, the snacks were different. There was a significant association between exposure condition and whether participants' assumptions were correct ($\chi^2(1)=5.97$, $p=.015$), with participants in the HED condition being more likely to have guessed correctly. This pattern of results may indicate that attempts to match the Low and High energy density foods were not completely successful.

Participants rated their certainty in their assertions as to whether or not the snacks differed between computer and pen and paper test days, and those data are shown in Figure 5.13. An independent ANOVA was conducted on certainty ratings, with correct assumption (yes, no) and exposure condition (LED, HED) as the between-subject factors. There was a weak trend for certainty ratings to be lower for correct assumptions than incorrect, across both exposure conditions, although this effect was not significant ($F(1, 47)=2.54$, $p=.117$). Certainty ratings did not differ between the exposure conditions (main effect of condition $F(1,47)=0.03$, $p=.866$), and differences in ratings between assumptions did not differ between conditions (interaction assumption x condition $F(1, 47)=0.03$, $p=.867$).

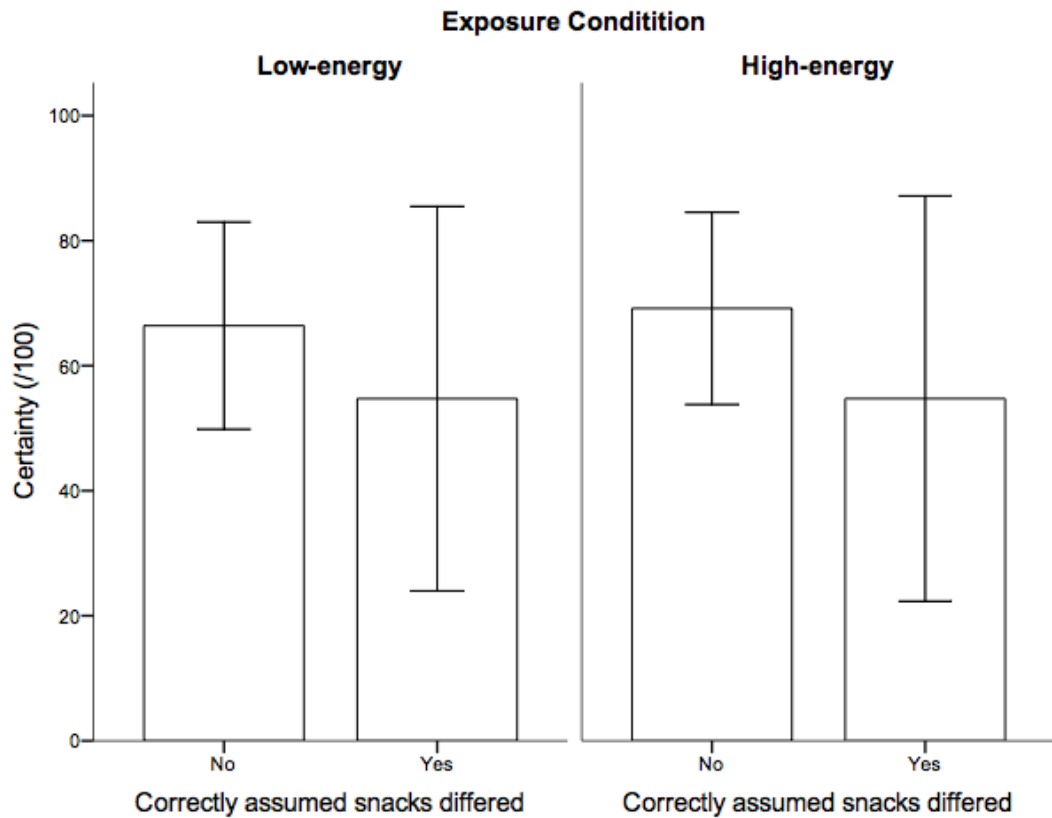


Figure 5.13 Rated certainty of response for whether snacks differed between computer and pen and paper test days in each exposure condition, by accuracy of assumption, for Experiment 5.

Of the 19 participants in the HED condition that correctly guessed the pink snacks differed between computer and pen and paper test days, responses on what they thought the differences were, were classified as follows: sweetness (37%); sweetness and texture (21%); texture (21%); texture and flavour (5%); flavour (11%); and one participant could not describe the difference (5%).

5.2.4. Exp. 5 Discussion

The overall aims of the thesis, this experiment was intended to establish whether effect of flavour consequence learning and learned satiety modulated the magnitude of SSS. On the first test day SSS was observed for the sample as a whole, with no statistical difference between conditions, which was to be expected at this baseline point. Pleasantness decline was significantly greater for the Eaten (sweet novel snack) food than the Uneaten savoury (Cracker) food. These findings support those of Experiments 1 and 2, which also reliably generated SSS. The Uneaten sweet food (Marshmallow) was subject to transfer effects (see Section 1.2.1.1: Sensory-Specific Satiety in Humans), resulting in pleasantness decline that was not significantly different from that of the Eaten food. To the extent that Uneaten foods share sensory properties, they may be subject to hedonic transfer from the Eaten food, and this phenomenon has been observed in previous studies (e.g. Guinard & Brun, 1998; Hetherington, et al., 2000; Johnson & Vickers, 1993; B. J. Rolls, et al., 1981; Weenen, et al., 2005). Both the test snack and the Marshmallow were sweet, so a transfer effect was to be expected. On the second SSS test day after four exposures, and on the final SSS test day after eight exposures, there was no evidence that SSS occurred during consumption of the test food.

Baseline pleasantness and novelty ratings differed between the foods, but not between conditions. The Eaten snack food was subject to lower pleasantness ratings and higher novelty ratings than either the Cracker or Marshmallow. Novel foods are prone to greater exposure effects (see Section 1.3.1.1: Mere Exposure), and that the test food was rated highly novel is in line with the pilot test results. The low pleasantness ratings for the test food at baseline were cause for concern, but did not create a floor effect: the Eaten food still presented a greater pleasantness decline than the Cracker, indicating the presence of SSS. However, three participants in the HED condition withdrew during the course of the Experiment because they disliked the HED test food. At the time, this event was deemed to be an indication of individual differences, but now appears to have been an important signal regarding the acceptance value of the HED food. The participants withdrew during exposure sessions, citing the large portion of the HED snack as unpalatable, but there was no evidence for dislike of the LED snack used in the first SSS test. In hindsight, the differences in acceptance between the LED and HED should have flagged up the possibility of detectable sensory differences between the two versions of the test food, and indicated that test foods were distinguishable from each other. It is possible that a

ceiling effect occurred with regard to the effect of learning: the HED version of the test food may not have had scope for increase in liking over exposures. However, at least one published study found pleasantness increases over the course of repeated exposure for foods that were rated below neutral on pleasantness at baseline (Pliner, 1982), and the findings presented here are not sufficient to provide the foundation of a strong conclusion in this respect.

Initial pleasantness ratings for the Eaten snack at each SSS test did not differ between test days, nor between groups. This finding indicates that neither FCL nor learned satiety took place as a result of the eight exposure sessions. The absence of positive findings for dietary learning in this experiment was both surprising and disappointing. Clearly the baseline group differences in pleasantness ratings for the Marshmallow are spurious, but the lack of measurable SSS on the second and final test days is difficult to explain.

Whether learning had taken place or not, SSS occurred on the first test day and should have persisted across the other SSS test days. The HED and LED foods may have been too similar in energy density to be differentiated, and this would explain the lack of group differences throughout the experiment. In addition to this, there was no evidence of any form of dietary learning, with pleasantness for the Eaten food remaining fairly static at all three test days, despite multiple exposures to the test food in between. This may indicate a lack of transference of any learned effect from the exposure foods to the Eaten food, but this is unlikely given their similarity.

Analysis of hunger ratings taken before, immediately after, and one hour after consuming the 200g portion on training days revealed a general trend for pre-exposure hunger to increase over the course of the eight exposures, though there were no group differences. Post-consumption hunger ratings were again similar between conditions across exposure sessions, though a non-significant divergence between the LED and HED conditions was observed, with the LED post-consumption hunger ratings remaining fairly static, and the LED ratings elevating slightly in the final four exposure sessions. Ratings of hunger 1-hour post consumption on exposure days again showed a non-significant trend to increase over the course of the experiment, but once more there were no group differences. The total energy-density difference may not be as important as the difference from zero, in other words, if the low-energy density snack had been lower in energy density, then differences may well have been more apparent between the LED and HED conditions.

All hunger ratings taken pre-exposure on test days were moderate, with none dropping below the midway of 250 on the 500-point scale. This finding indicates that hunger generated by the three-hour fast was sufficient, but ideally ratings should have been higher. Other experiments have found a three-hour fast after a controlled breakfast is sufficient to induce learning (e.g. 2007; Yeomans, Gray, & Conyers, 1998), so perhaps the absence of evidence for FCL and learned satiety in this experiment is more likely to be a consequence of an insufficient satiating effect of the HED food.

Methodologically this experiment raised good questions about learning in a snack context, and energy density, but it also highlighted the result that changes to the decline in pleasantness for the Eaten food were apparent after just four exposures, and the final four did not add anything to these results. Thus, as this experiment did not give rise to dietary learning, the effects of FCL and learned satiety on SSS could not be measured.

5.3. Experiment 6

5.3.1. Exp. 6 Background

Experiment 5 investigated the effect of prior learning about foods on the magnitude of sensory-specific satiety. Results from that study indicated that the magnitude of SSS declined significantly after 4 exposures to a previously-novel food, but this change did not differ significantly between the two conditions exposed to high- and low-energy versions of the test food. The most probable explanation was that the energy difference between the two versions of the test food (142 kcal / 200g portion) may have been insufficient to show clearly any group differences, and / or that the low-energy version was not actually adequately low in energy (108 kcal / 200g portion) to provide a control group for comparison to detect effects of dietary learning. This interpretation leaves open the possibility that energy differences may have a differential effect on the extent to which SSS develops, and that a better test of this hypothesis is required. In terms of flavour-consequence learning, the energy difference used here (142 kcal) is not that different to studies which have found increased liking with exposures, but most successful studies used a much lower contrast condition (see Section 1.3.3.1: Flavour-Based Learning).

Experiment 6 therefore had the same basic aims as Experiment 5, but used a paradigm that has previously been reported to support FCL in humans. Another element arising from the present study is the additional contrast of the relevance of two of the main models of flavour liking acquisition, FFL and FCL, and the interaction between them, on expression of SSS. Experiment 5 was useful in establishing that four exposures were sufficient to induce some evidence of a learned change since SSS had diminished at that time, and so this timescale was adopted for Experiment 6. The energy difference between high- and low-energy exposure portions was 152 kcal / 400g portion, but the low-energy version had a much lower baseline of just 7 kcal / 400g portion, and the stimuli had been successfully employed to generate FFL and FCL in this laboratory in previous work (Yeomans, Gould, Bertenshaw, & Chambers, 2009; Yeomans, Leitch, et al., 2008).

5.3.2. Exp. 6 Method

5.3.2.1. Exp. 6 Design

The experiment used a mixed design, contrasting changes in pleasantness ratings of three snack foods (the Eaten test food, an Uneaten savoury and an Uneaten sweet contrast) on two separate test days, before and after four exposures to a liquid version of the Eaten food, between four conditions. Conditions were differentiated by the drink consumed in the exposure phase, which varied in combinations of sweetness (sweetened; unsweetened) and energy density (high-; low-) to create four exposure groups (see Table 5.5). This design was modelled closely on a recent successful study of FFL and FCL in this laboratory (Yeomans, et al., 2007).

Table 5.5 Experiment 6 energy-density and sweetness manipulation of the test food in experimental conditions

Condition	Exposure drink
Unsweetened LED	Low-energy density, unsweetened
Sweetened LED	Low-energy density, sweetened
Unsweetened HED	High-energy density, unsweetened
Sweetened HED	High-energy density, sweetened

5.3.2.2. Exp. 6 Participants

Inclusion and exclusion criteria for recruitment are detailed in (see Section 2.3: Participant Selection). In addition, potential participants attended the laboratory for a sweet-screening test, and Twenty-four men and Twenty-four women were recruited from those classified as sweet-likers. Non-likers were excluded since they may have exhibited lower baseline pleasantness ratings for the sweet exposure drinks and may also have shown minimal increase in liking for the stimulus over time.

The screening procedure has been used successfully in previous learning studies in this laboratory, where sweet-liking is a criterion of participant recruitment (e.g. Mobini, et al., 2007; Yeomans, Leitch, et al., 2008; Yeomans & Mobini, 2006; Yeomans, et al., 2007). Screening involved the tasting and rating of two samples of water, and two samples of a 10% sucrose solution. Samples were approximately 30 g and served in 60 ml glass vials,

similar in size and shape to tall shot glasses, straight from the refrigerator maintained at $<5^{\circ}\text{C}$. Thirty grams is sufficient for tasting in order to complete the subjective ratings, and not large enough for energy content to be a confound to the ratings. The four vials were placed on a tray in a random order and labelled alphabetically. Participants sampled the solutions in the order they were presented on the tray, and gave ratings on pre-printed 100 mm VAS (see Appendix N) for the following attributes: sweet, sour, pleasant and bitter. Participants were classified as sweet-likers if the average pleasantness rating for the two sucrose solutions was greater than 50 mm. Ambiguous cases (e.g. If the pleasantness rating was greater than 50 mm for one sucrose solution and less than 50 mm for the other) were resolved by asking the participant if they sweetened their hot drinks such as tea and coffee. An affirmative response meant that they were then classified as a sweet-liker.

The ages of participants ranged from 18 to 48 years old (mean 22.8 ± 0.4). BMI ranged from 18.0 to 30.8 kg/m^2 (mean 22.9 ± 0.4). TFEQ-R scores ranged from 0 to 6 (mean 2.9 ± 0.2) and self-reported average daily caffeine intake from 0 to 480 mg (mean 127.5 ± 16.0). Participants were randomly assigned to one of four exposure-drink conditions, giving 12 in each condition (6 men and 6 women). Neither age ($F(3, 44)=2.14$, $p=.109$), BMI ($F(3, 44)=0.76$, $p=.523$), TFEQ-R scores ($F(3, 44)=2.54$, $p=.069$) nor average daily caffeine intake ($F(3, 44)=0.50$, $p=.682$) differed significantly between the four conditions.

5.3.2.3. Exp. 6 Foods and Drinks

Exposure drinks were four versions of the same fruit drink previously used successfully in dietary learning experiments in the Ingestive Behaviour Laboratory at the University of Sussex (Yeomans, Gould, Bertenshaw, et al., 2009; Yeomans, Leitch, et al., 2008). Two low-energy density (LED) drinks were matched on energy content, and two high-energy density (HED) drinks were matched on energy content. One of each of the LED and HED drinks was unsweetened, and one was sweetened. The sweetened drinks were matched on pleasantness and sweetness, and all drinks were of the same flavour (Yeomans, Leitch, et al., 2008).

The fruit-based drinks were as viscous as water, and a transparent pink in colour, similar to a fruit squash. The drinks comprised fruit juice (Cranberry-orange light juice drink, Tesco plc); water; and the flavours "kiwi" and "mandarin" (IFF). Energy density and sweetness were manipulated with the addition of aspartame (Ajinomoto, Switzerland) to

the low-energy sweetened drink; maltodextrin (Complex-Carbs, Garnell Nutrition) to the high-energy unsweetened drink; and sucrose (Tate & Lyle, Nottingham) to the high-energy sweetened drink. Ingredients and quantities for each of the four drinks are shown in Table 5.6.

Table 5.6: Ingredients per 400g portion of the four test drinks in Experiment 6

Ingredients (g)	Drink version			
	LED-U	LED-S	HED-U	HED-S
Cranberry and orange juice	120.00	120.00	120.00	120.00
Water	280.00	280.00	240.00	240.00
Kiwi flavour	0.50	0.50	0.50	0.50
Mandarin flavour	0.50	0.50	0.50	0.50
Aspartame	N / A	0.14	N / A	N / A
Maltodextrin	N / A	N / A	40.00	N / A
Sucrose	N / A	N / A	N / A	38.00

The LED-U drink was produced by mixing all the ingredients together at room temperature. For each of the other three drinks, the aspartame, maltodextrin or sucrose was dissolved in a portion of the water that had been boiled and still remained hot. Once fully dissolved, the other ingredients were added and thoroughly mixed together. Drinks were stored in sealed plastic bottles in a refrigerator maintained at $<5^{\circ}\text{C}$. Macronutrient and energy content for the drinks are shown in Table 5.7.

Table 5.7 Macronutrient and Energy composition of the four versions of the test drink in Experiment 6

	Drink Version			
	Low-energy		High-energy	
Per 100 g	Unsweet	Sweet	Unsweet	Sweet
CHO (g)	0.3	0.3	9.8	8.8
Protein (g)	0.0	0.0	0.0	0.0
Fat (g)	0.0	0.0	0.0	0.0
Energy (kcal)	1.8	1.8	39.8	39.8
Per 400 g portion				
CHO (g)	1.2	1.2	39.2	39.2
Protein (g)	0.0	0.0	0.0	0.0
Fat (g)	0.0	0.0	0.0	0.0
Energy (kcal)	7.2	7.2	159.2	159.2

In both the original studies in which these formulations were used, the solid food was a sorbet made from the low-energy unsweetened version of the drink (Yeomans, Gould, Bertenshaw, et al., 2009; Yeomans, Leitch, et al., 2008). This experiment aimed to explore SSS in a snack context, and as such the use of a sorbet was both inappropriate and impractical. It would have been difficult to maintain the frozen state for a small, 50 g portion, and as the sorbet melts it reverts back to the liquid state that matches the drinks, allowing little time in the mouth. For these reasons, an entirely new snack food was developed.

Extensive benchwork was conducted with the aim of creating a jelly-like snack food from the low-energy unsweetened (control) drink, that would be moderately pleasant (to minimise ceiling and floor effects) and novel (to ensure prior learning did not interfere with pleasantness ratings). Pilot testing was carried out at each stage of development to ensure that the jelly was closely matched to the drink in flavour and flavour intensity. The jelly was created from the low-energy unsweetened drink by adding powdered gelatine (SuperCook, Leeds). Results from the initial pilot tests indicated the jelly was rated more bitter and less intense in flavour than the drink, so the flavouring levels were increased, and a small amount (38 g / 400 g portion) of sucrose added. In the final pilot test, eleven participants (8 women and 3 men) were presented with samples (5 - 10 g) of the jelly and control drink in 50 ml clear plastic containers on a tray. Sensory and hedonic evaluations were completed using 100 mm pre-printed VAS (see Appendix O). Participants rated the drink and jelly on the following properties: sweet; bitter; pleasant; and novel. Participants were then asked to compare the drink to the jelly on two further VAS: "How similar is the flavour of the drink to the flavour of the jelly?" and "How similar is the intensity of the flavour of the drink to the intensity of the flavour of the jelly?". The left end of both these scales was anchored with "Not at all similar" and the right end anchored with "Extremely similar".

Single-sample t-tests were conducted on pleasantness ratings, with 50 as the test value, as this was the mid-point of the possible ratings from 0 to 100. Results for pleasantness and novelty ratings are shown in Table 5.8. The ratings for similarity of flavour, and for similarity of flavour intensity (between the drink and the jelly) were judged to be sufficient if the ratings on each of these properties differed significantly from zero (i.e. If the drink and jelly were rated highly similar on flavour and flavour intensity). Single-sample t-tests were conducted on these ratings, with zero as the test value (results are shown in Table 5.9).

Table 5.8: Pleasantness and novelty ratings for the test drink and jelly in the pilot for Experiment 6

	Pleasantness	Novelty
Drink	44.2 (\pm 6.2)	57.5 (\pm 4.7)
Jelly	39.2 (\pm 7.3)	53.5 (\pm 6.0)

* Indicates a pleasantness rating significantly different to the test value of 250 ($p < .05$).

Table 5.9: Ratings for similarity of flavour and flavour intensity of the test drink and jelly in the pilot for experiment 6

	Flavour	Rating Flavour intensity
Similarity between the jelly and the drink	69.5 (\pm 6.0)*	48.8 (\pm 6.3)*

* Indicates rating significantly different to zero

In addition, sensory and hedonic measures showed the drink and jelly were well matched: paired t-tests revealed that the jelly and the drink did not significantly differ on ratings of pleasantness ($t = 0.8$ (10), $p = 0.5$); novelty ($t = 0.9$ (10), $p = 0.4$) and sweetness ($t = 1.5$ (10), $p = 0.2$). The drink received a higher bitterness rating (29.8 ± 9.2) than the jelly (16.8 ± 4.6) and although this difference did reach statistical significance ($t = 2.5$ (10), $p = 0.03$), both stimuli were rated low on bitterness and the difference was not enough to cause concern. The final version of the jelly thus met the criteria of moderate pleasantness and high novelty, and matched the control drink for flavour, flavour intensity, pleasantness, novelty and sweetness.

The jelly was mixed up in batches of 400g and produced in the following way: the gelatin granules and sucrose were dissolved in half of the water that had been boiled. The fruit juice, flavourings and remaining cold water were then mixed in thoroughly. Whilst still in liquid form, the mixture was divided into 50g portions for SSS testing, and refrigerated to solidify. Ingredients, quantities and macronutrient and energy content are shown in Table 5.10.

Table 5.10: Ingredients, quantities, and macronutrient and energy content of the Eaten food for Experiment 6

	per 400g batch Quantity (g)	kcal	per 50g portion		Fat
			Protein	CHO	
Juice	120.00	0.90	0.00	0.15	0.00
Water	280.00				
kiwi	0.90				
mandarin	0.90				
gelatin	7.00	2.98	0.75	0.00	0.00
sugar	5.50	2.75	0.00	0.69	0.00
Total		6.63	0.75	0.84	0.00

In all tests for sensory-specific satiety, 50 g of the jelly was presented as the Eaten food. The uneaten foods were two sensorially different snacks selected from previous experiments that met the criteria of moderate pleasantness (to minimise ceiling and floor effects) and novelty: Sainsbury's Vanilla Marshmallows (sweet) and Worcester Sauce Minis (Ryvita) (savoury). Energy and macronutrient content of the foods are shown in Table 5.11.

Table 5.11: Macronutrient and energy composition of the Uneaten foods in Experiment 6

	Per 100g	
	Ryvita	Marshmallow
CHO (g)	71.9	78.5
Protein (g)	6.9	4.1
Fat (g)	2.6	0.0
Energy (kcal)	339.0	330.0

5.3.2.4. Exp. 6 Rating Scales

In both SSS tests, all ratings were taken using electronic VAS with SIPM software (see Section 2.4.1: Laboratory Setup). Ratings were taken for appetite ('hungry', 'full' and 'thirsty'), hedonics ('pleasant', 'desire to eat more of this') and sensory attributes ('novel', 'sweet', 'sour', 'savoury', and 'bitter') of the foods. Mood ratings were taken ('lethargic', 'alert', 'relaxed' and 'tense'), but as these served only as distractors, these ratings were not analysed.

In each of the eight exposure sessions, participants completed ratings on pre-printed 100mm VAS forms (see Appendix P). The 'not at all' anchor always appeared on the left, and the 'extremely' anchor on the right of the scale. The VAS were set out on four sheets of A4 paper, which discouraged participants from referring back to previous responses. Mood, appetite, sensory and hedonic ratings were the same as those presented in the SSS testing sessions, except that the evaluation of 'savoury' was omitted, as the exposure stimuli were all sweet and this rating was redundant.

5.3.2.5. Exp. 6 Procedure

Each participant attended the laboratory on 6 days, with an upper limit of 14 days between appointments. Experiment 5 required testing sessions to fall on non-consecutive days, a method common to many dietary learning experiments, to avoid stimulus fatigue, but as there is no evidence of such fatigue, and because this experiment required very long periods of time to complete, the restriction was dropped for the current study.

Participants fasted from 23:00h on the night before laboratory sessions, consuming nothing but water until arrival at the laboratory, at which point the controlled breakfast was provided (see Section 2.4.2: Laboratory Breakfasts). After breakfast, participants were free to leave the laboratory, but continued fasting (water was allowed) until they returned for testing, which took place three hours after the breakfast appointment, in a snack context. Fasting between breakfast and laboratory sessions remained at three hours for this experiment, as results from Experiment 5 confirmed that three hours was sufficient to induce moderate hunger, which as a motivational state would facilitate the dietary learning that the study aimed to induce (see Section 1.3.3: Dietary Learning).

On the first and final test days, participants completed the SSS testing paradigm (see Section 2.1: Methodology and Measurement of SSS in the Literature). Mood, appetite, sensory and hedonic ratings were completed by electronic VAS administered by SIPM software (see Section 2.4.1: Laboratory Setup), and testing was carried out in accordance with the standard SSS testing procedure (see Section 2.5: General Procedure). Samples of three test foods were presented in the pre-consumption and post-consumption phases of SSS testing: the test food (a sweet jelly, always presented as Food A); savoury Ryvita (always presented as food B); and marshmallow (always presented as Food C). Foods were not counterbalanced during in SSS testing. The aim of the experiment was to ascertain if dietary learning (induced by pairing the CS flavour of the jelly/drinks with a UCS of sweetness, high-energy content, or both) would modulate the magnitude of SSS experienced when consuming the CS-flavoured jelly post-exposure. As such, during the consumption phase of SSS testing, 50g (see Section 2.5: General Procedure) of the jelly was presented (as the Eaten food). The Ryvita and marshmallow (Uneaten foods) were presented at room temperature, and the jelly was served from a refrigerator maintained at <5°C.

On the intervening four test days, participants completed an exposure session and consumed a 400 g fixed portion of one of the drinks (either low- or high-energy density, and either sweetened or unsweetened, according to the experimental exposure condition to which the participant was allocated). Exposure sessions took place in one of four open testing booths divided by screens, as in Experiment 5. Mood, appetite, sensory and hedonic ratings were completed by hand on pre-printed 100 mm VAS forms (see Appendix P). All instructions were provided on the VAS forms. Initially participants completed a page of ratings for mood and appetite, after which they were instructed to call the experimenter. The experimenter then provided the exposure drink in a 400ml white polystyrene cup, with a translucent fitted plastic lid. A drinking straw was inserted through the centre of the lid and to the bottom of the cup. The cup was presented on a white plastic tray (28.3 x 21.4 cm) along with a napkin. The second page instructed participants to taste the exposure drink, and rate it on sensory and hedonic scales. Instructions specified that participants then finish the drink. After the drink was consumed, another page repeated the mood and appetite ratings, after which participants were once again instructed to call the experimenter. The experimenter removed the three pages of completed ratings from the response pack, and returned the fourth page to the participant. Participants were then free to leave the laboratory, and instructed to consume nothing but water for one hour, after which they completed the final VAS sheet of repeated mood and appetite ratings. Participants were then free of consumption restrictions, and returned the final VAS sheet upon their next appointment with the experimenter.

At the end of the final test session, participants were asked to complete a written structured debrief (see Appendix Q). Firstly, participants were asked "In your own words, please write one or two sentences on what you think this experiment was about" and space was provided for the response. They then turned the page to reveal one further question, to which they were required to respond 'yes' or 'no': "How similar was the taste of the drink (on pen & paper test days), and the taste of the jelly (on computer test days)?". A 100 mm VAS was provided for the response. One end of the scale was anchored with "Not at all similar" and the other with "Extremely similar".

5.3.3. Exp. 6 Results

5.3.3.1. Exp. 6 Initial Pleasantness and Novelty Ratings

Test foods were selected and developed to ensure they were rated moderately pleasant and novel to some degree, and as with Experiment 5, the snacks were not counterbalanced as Eaten food in SSS testing: the Eaten food was always the jelly, and the Uneaten foods the Ryvita (savoury) and Marshmallow (sweet). It was important to test the assumptions made of the foods used during testing, therefore initial ratings of pleasantness and novelty (made upon first contact with the foods during the pre-consumption phase of the first SSS test) were analysed.

A mixed ANOVA was conducted on initial pleasantness ratings with Food as the within-subject factor (Eaten jelly, Uneaten Ryvita, Uneaten marshmallow), and Drink Exposure Condition (LED-U, LED-S, HED-U, HED-S) as the between subject factor (data shown in Figure 5.14). The main effect of Food was statistically significant ($F(2, 88)=27.24$, $p<.001$), and pairwise comparisons revealed that the Marshmallow was rated more pleasant than both the Ryvita ($p<.001$) and the jelly ($p<.001$), though the contrast between the jelly and Ryvita was not significant ($p=.122$). Initial pleasantness ratings for the foods did not differ between Drink Exposure Conditions (main effect of Condition $F(3, 44)=0.770$, $p=.517$), nor did differences in pleasantness ratings for the foods differ between conditions (interaction Food x Condition $F(6, 88)=1.786$, $p=.111$).

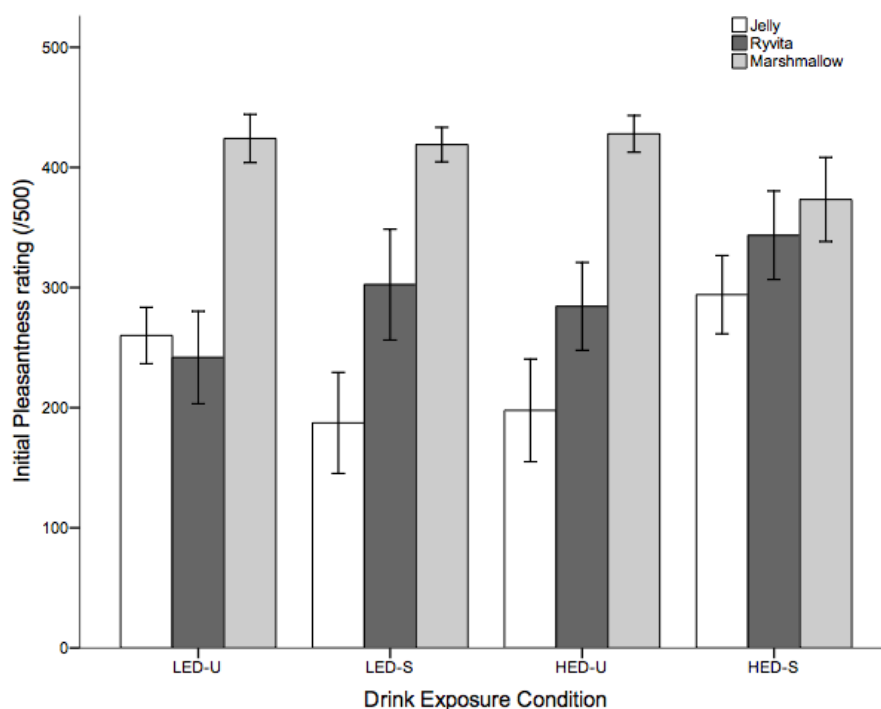


Figure 5.14: Initial pleasantness ratings for each food by experimental condition in Experiment 6.

Initial novelty ratings were also analysed using a mixed ANOVA, with Food (Eaten jelly, Uneaten Ryvita, Uneaten marshmallow) as the within-subject factor and Drink Exposure Condition (LED-U, LED-S, HED-U, HED-S) as the between-subject factor (data shown in Figure 5.15). The main effect of Food was significant ($F(2, 88)=5.844$, $p=.004$), and pairwise comparisons revealed that the Ryvita was rated as significantly more novel than both the jelly ($p=.034$) and the marshmallow ($p=.009$), though the jelly and marshmallow were rated similarly ($p=1$). Neither the main effect of Condition ($F(3, 44)=0.270$, $p=.846$), nor the interaction between Condition and Food ($F(6, 88)=1.039$, $p=.406$) reached significance, suggesting that novelty ratings did not differ between groups, nor between foods as a function of Drink Exposure.

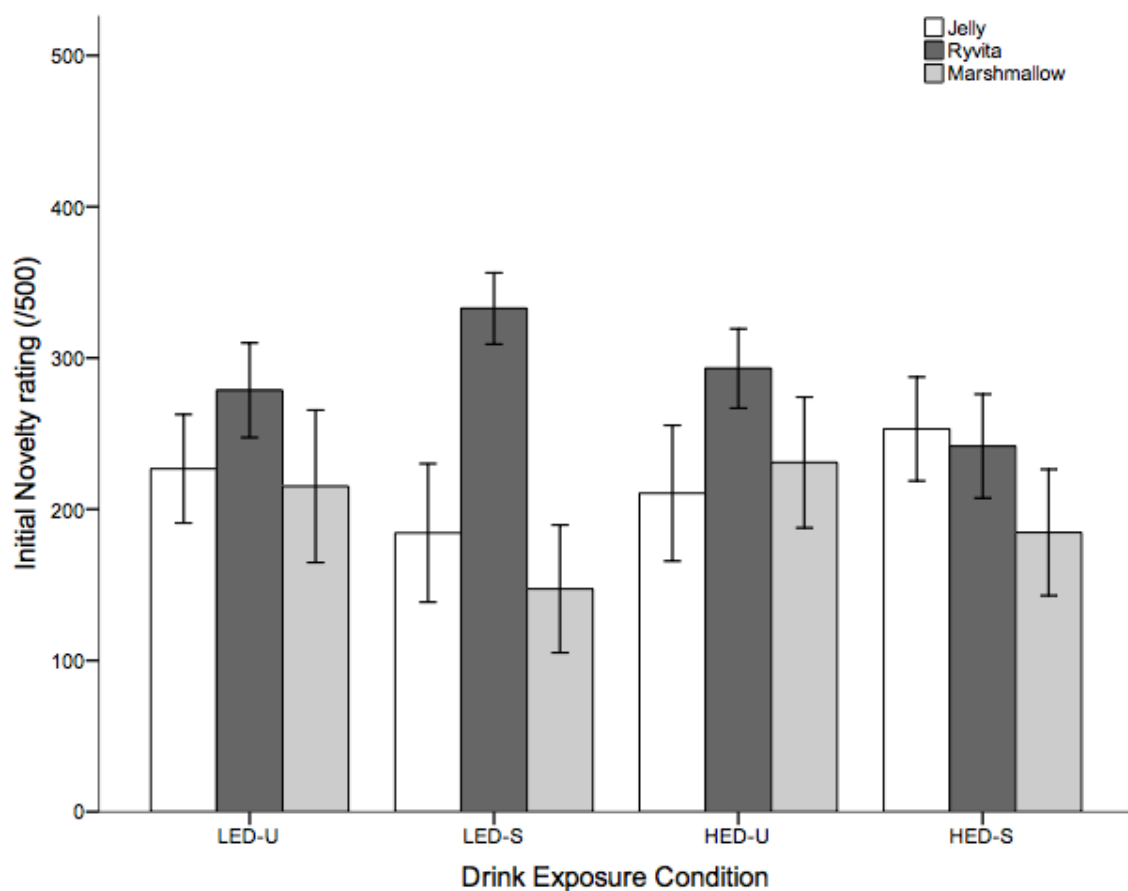


Figure 5.15: Initial novelty ratings for each food by experimental condition in Experiment 6.

Although significant differences arose between foods for both pleasantness and novelty ratings, all ratings were within the extremes of the 500-point scale, allowing scope for both increase and decrease during the experiment.

5.3.3.2. Exp. 6 Sensory-Specific Satiety

In order to assess SSS, a separate ANOVA was conducted for each of the two test days, on Change In Pleasantness, with Food as the within-subject factor (Eaten jelly, Uneaten Ryvita, Uneaten Marshmallow), and Drink Exposure Condition as the between subject factor (LED-U, LED-S, HED-U, HED-S). Change In Pleasantness ratings between Foods failed to meet the assumption of Sphericity on both SSS Test Days (Test Day 1, Mauchly's $W(2)=.79$, $p=.006$; Test Day 2, Mauchly's $W(2)=.86$, $p=.042$) so the following statistics are reported with the Greenhouse-Geisser adjustment where appropriate.

Change In Pleasantness data for Test Day 1 are shown in Figure 5.16. The main effects of Food ($F(1.65, 72.48)=1.01$, $p=.358$), Condition ($F(3, 44)=0.82$, $p=.492$), and the interaction between Food and Condition ($F(4.92, 72.48)=0.45$, $p=.80$) all failed to reach statistical significance. The results indicate that there were no statistically significant differences in the Change In Pleasantness ratings on test day one between the Foods, and therefore the data show no evidence for sensory-specific satiety. On the first SSS test day, at baseline, there were no treatment differences between the groups, and as expected no differences in Change In Pleasantness ratings between Drink Exposure Conditions, and that Change In Pleasantness ratings did not differ between foods as a function of Condition.

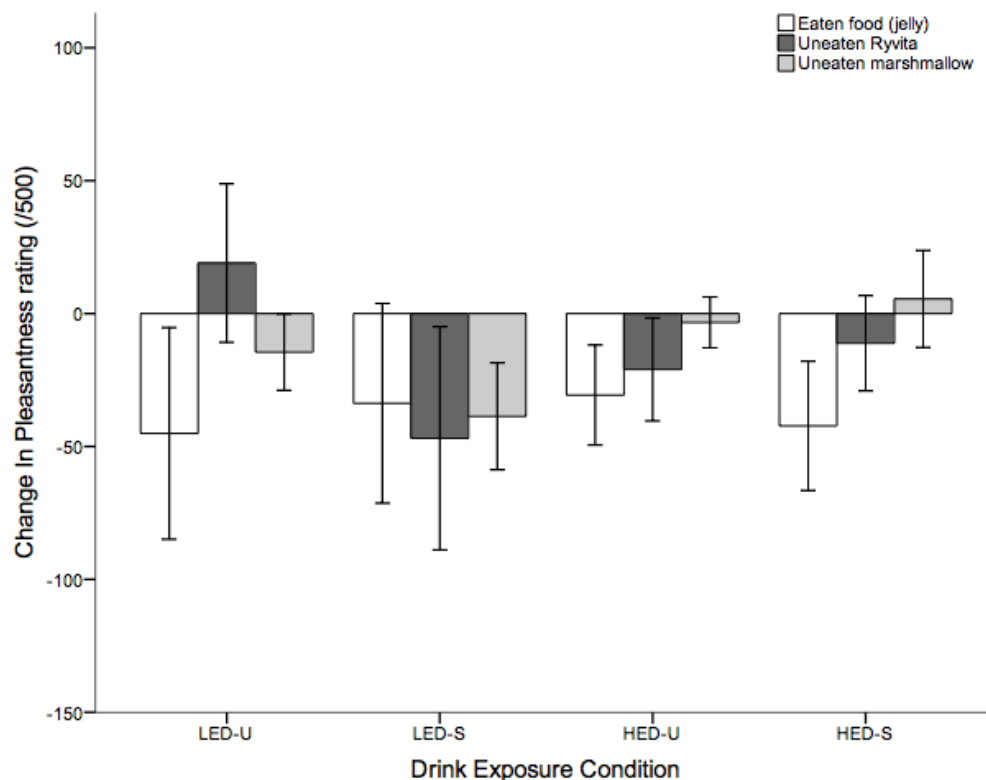


Figure 5.16: Change In Pleasantness ratings for each food in each exposure condition on SSS Test Day 1 for Experiment 6.

Change In Pleasantness data for Test Day 2 are shown in Figure 5.17. The main effects of Food ($F(1.76, 77.38)=0.56$, $p=.549$), Condition ($F(3, 44)=0.78$, $p=.514$), and the interaction between Food and Condition ($F(5.28, 77.38)=1.037$, $p=.404$) all failed to reach statistical significance. The results mirror those of the first test day, indicating no significant differences in the Change In Pleasantness ratings on test day two between the Foods or Drink Exposure Conditions, and that Change In Pleasantness ratings did not differ between foods as a function of Condition, and thus the data show no evidence of sensory-specific satiety on the final test day.

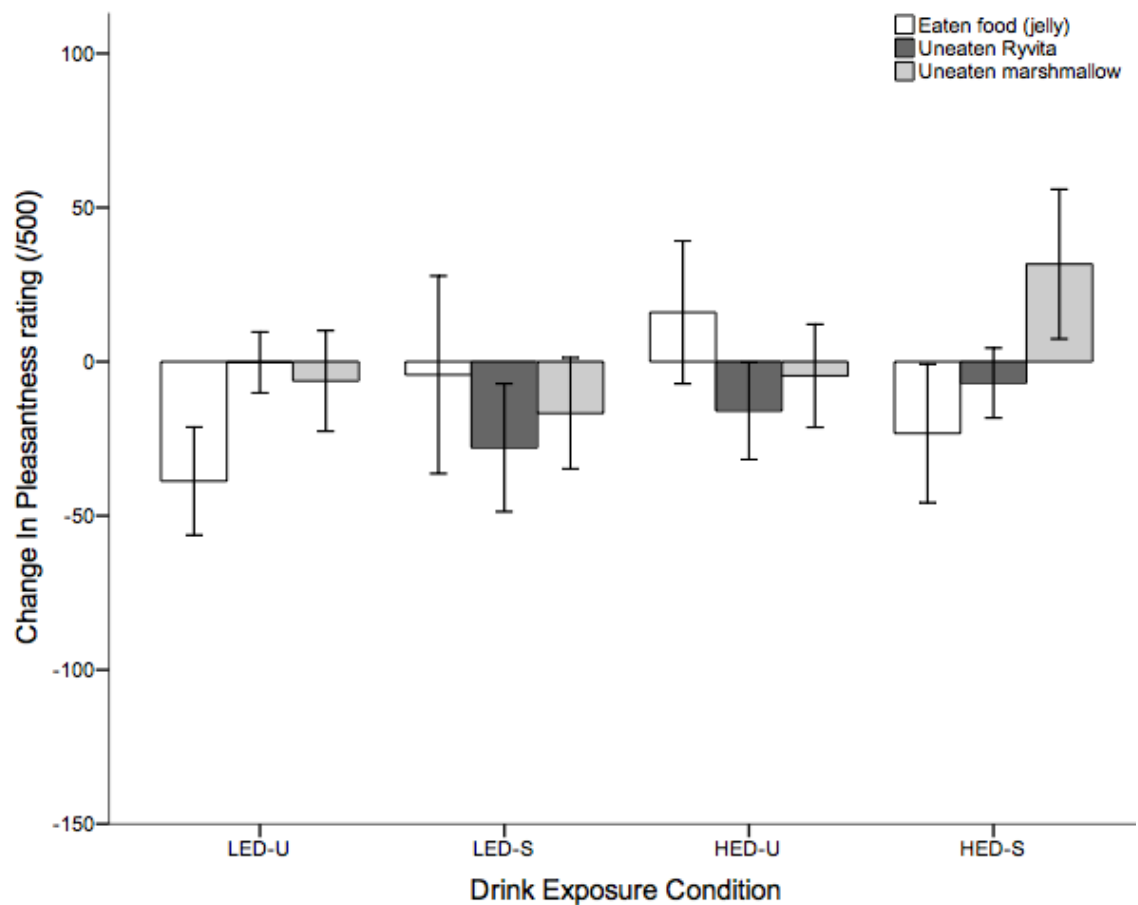


Figure 5.17: Change In Pleasantness ratings for each food in each exposure condition on SSS Test Day 2 for Experiment 6.

5.3.3.3. Exp. 6 Change in Hedonic Ratings Across SSS Test Days

In order to establish whether exposure to one of the four drinks (which differed by manipulations to energy density and sweetness) altered the changes in hedonic ratings to the jelly (based on the LED-U drink), a mixed ANOVA was conducted on Change In Pleasantness ratings for the Eaten food (jelly), with SSS Test Day (test day 1, test day 2) as the within-subject factor, and Drink Exposure Condition (LED-U, LED-S, HED-U, HED-S) as the between-subject factor (data shown in Figure 5.18). Change In Pleasantness ratings for the jelly did not differ significantly between Test Days ($F(1, 44)=1.75$, $p=.193$), nor between Drink Exposure Conditions ($F(3, 44)=0.55$, $p=.652$). The interaction between Test Day and Condition was also non-significant ($F(3, 44)=0.20$, $p=.897$), indicating that Change In Pleasantness did not differ significantly between days across exposure conditions.

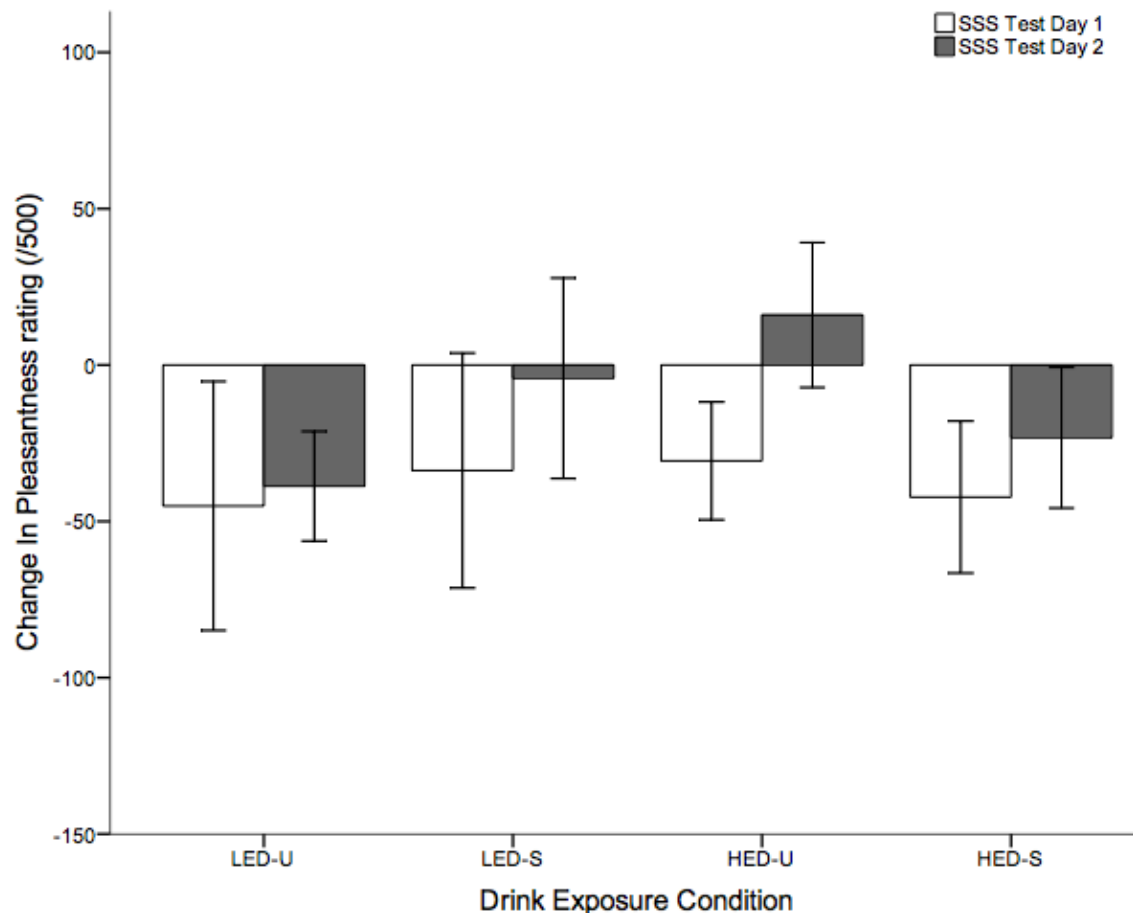


Figure 5.18: Change In Pleasantness ratings for the Eaten food on each SSS Test Day for each exposure condition in Experiment 6.

As with Experiment 5 (see Section 5.2.3.3), the ANOVA was repeated, this time conducted on Change In Desire To Eat More of the Eaten food, with Test Day as the within-subject factor (test day 1, test day 2) and Exposure Condition (LED-U, LED-S, HED-

U, HED-S) as the between-subject factor (data shown in Figure 5.19). As with Change In Pleasantness ratings, there were no significant differences in Change In Desire To Eat more, either between Test Days ($F(1, 44)=0.09, p=.765$), between Drink Exposure Conditions ($F(3, 44)=0.16, p=.920$), nor were there differences between days across conditions (interaction between Test Day and Condition $F(3, 44)=1.81, p=.160$).

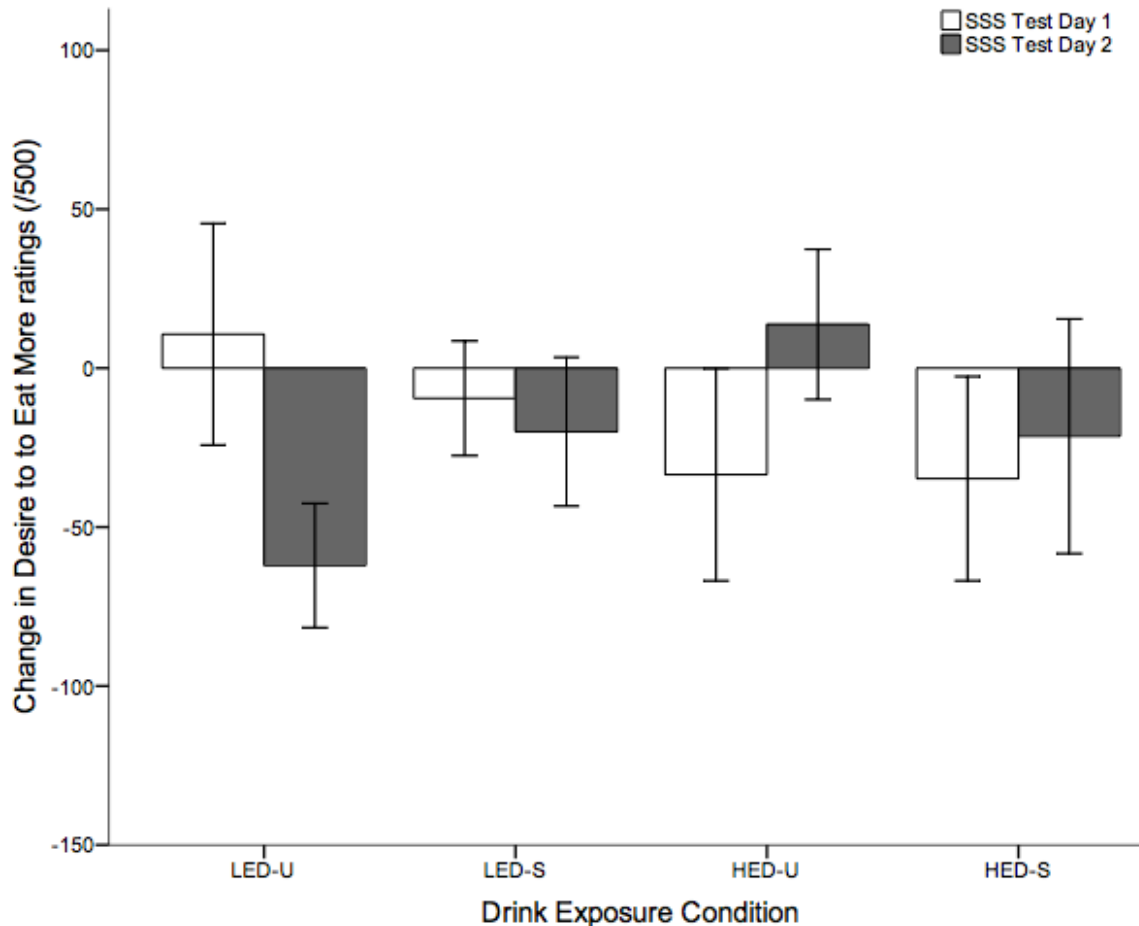


Figure 5.19: Change in Desire To Eat ratings for the Eaten food on each SSS Test Day for each exposure condition in Experiment 6.

5.3.3.4. Exp. 6 Changes in Initial Pleasantness Ratings for the Eaten Food Across SSS Test Days

If FFL or FCL had occurred as a result of repeated exposure to the drinks, then this would be reflected in the rated pleasantness of the Eaten food between test days. FFL would result in an increase in pleasantness ratings from the groups exposed to the sweetened drinks (LED-S and HED-S), and FCL would result in an increase in pleasantness ratings from the groups exposed to the high-energy drinks. If both FFL and FCL had co-occurred, then we would expect to find the greatest increase in pleasantness ratings for the Eaten food from the group exposed to the high-energy density sweetened version of the drink.

A mixed ANOVA was conducted on pleasantness ratings for the Eaten food (jelly) during the pre-consumption phase of SSS testing, with SSS test day (test day 1, test day 2) as the within-subject factor, and Drink Exposure Condition (LED-U, LED-S, HED-U, HED-S) as the between-subject factor (data shown in Figure 5.20).

In general, the jelly was rated lower in pleasantness in the LED-S and HED-U conditions than in the LED-U and HED-S conditions, but this difference was not statistically significant (main effect of Condition $F(3, 44)=2.56$, $p=.095$). Unexpectedly, the pleasantness ratings for the jelly changed very little after four exposures to the similarly flavoured drink, with a non-significant main effect of Test Day ($F(1, 44)=0.00$, $p=.983$). In addition, the interaction between Test Day and Condition also failed to reach significance ($F(3, 44)=0.06$, $p=.980$), indicating that any changes in rated pleasantness between the first and final test days were no different across the conditions, and therefore across the four types of exposure drink. Thus, surprisingly, these data suggest that there was no evidence for either FFL or FCL in this study.

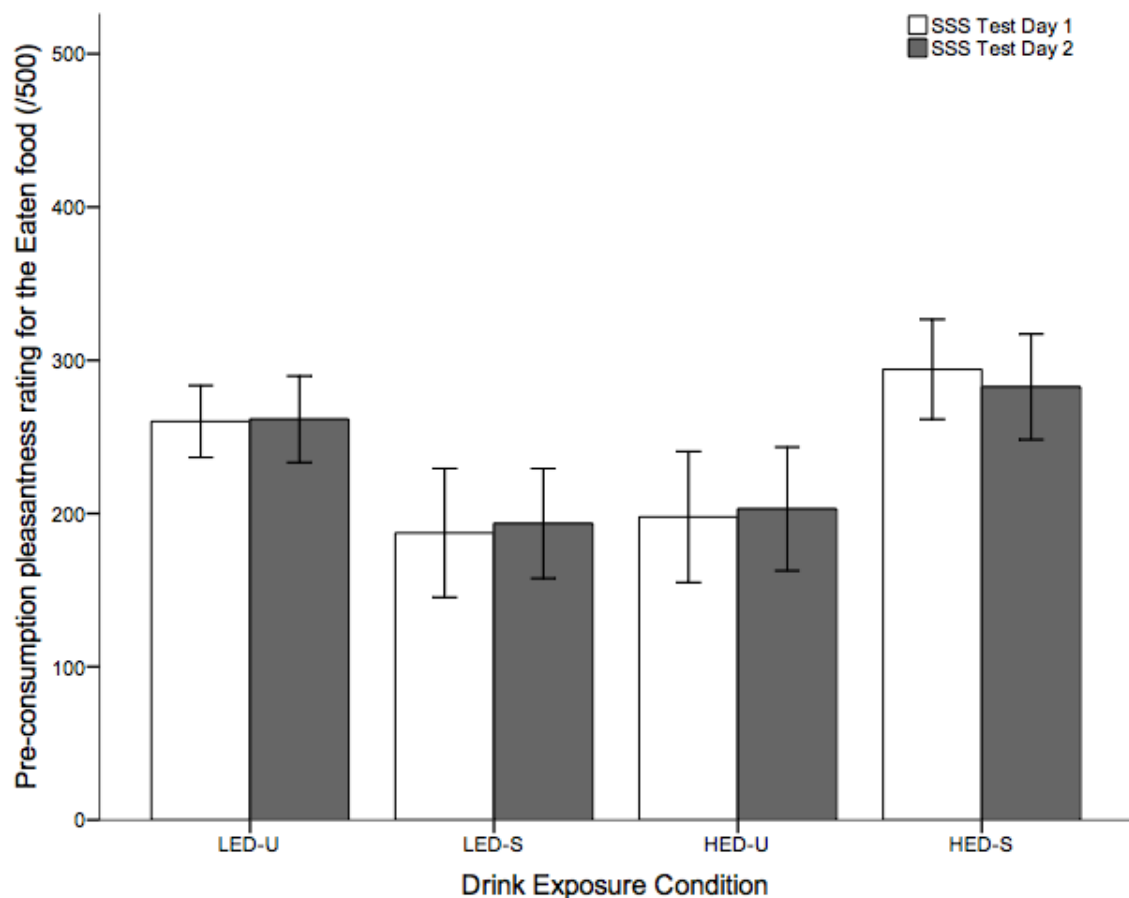


Figure 5.20: Pleasantness ratings for the low-energy test food on each SSS Test Day for each exposure condition in Experiment 6.

5.3.3.5. Exp. 6 Changes in Initial Novelty Ratings for the Eaten Food Across SSS Test Days

If the jelly were sufficiently similar in taste to the drinks, then novelty ratings for the Eaten food would be expected to decline after four exposures to a version of the drink. To test this, a mixed ANOVA was conducted on novelty ratings for the Eaten food (jelly) during the pre-consumption phase of SSS testing, with SSS test day (test day 1, test day 2) as the within-subject factor, and Drink Exposure Condition (LED-U, LED-S, HED-U, HED-S) as the between-subject factor (data shown in Figure 5.21). Novelty ratings for the Uneaten food (jelly) did not differ significantly between test days (main effect of Test Day $F(1, 44)=2.35$, $p=.132$), nor between Drink Exposure Conditions ($F(3, 44)=0.23$, $p=.877$). Although a trend for these ratings to decline on the second test day was observed in all groups except the LED-S, which rated the jelly as more novel after four exposures to the low-energy sweetened drink, the interaction between Test Day and Condition was not statistically significant ($F(3, 44)=2.01$, $p=.127$). Once again, surprising results: in this case indicating that familiarity with the exposure drink did not significantly transfer to the Eaten food (jelly) on the final SSS test day.

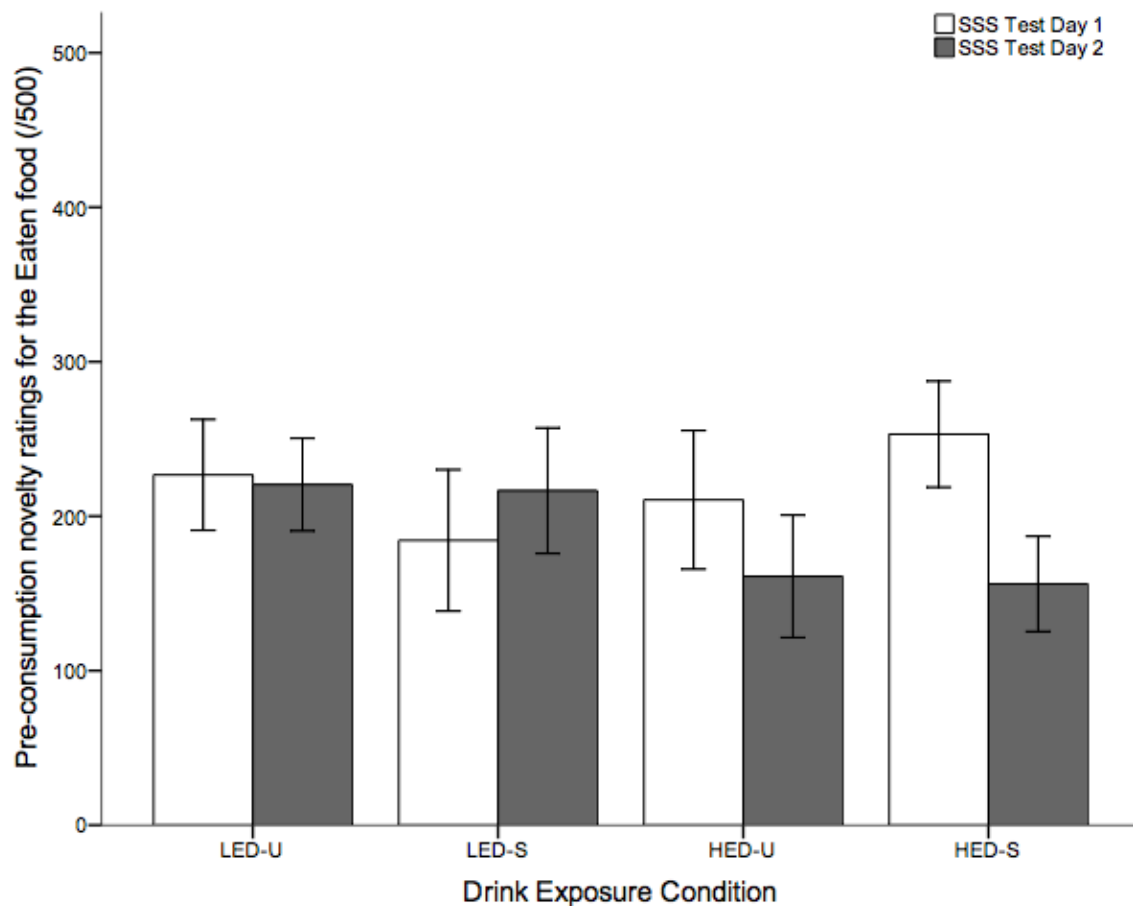


Figure 5.21: Novelty ratings for the Eaten food on each SSS Test Day for each exposure condition in Experiment 6.

5.3.3.6. Exp. 6 Hunger Ratings

In order to assess whether repeated exposure led to a progressive increase in the degree to which rated hunger declined when the food was eaten, and whether any such change was greater in the HED than LED condition, series of three mixed ANOVAs were conducted on hunger ratings taken at the start of each exposure sessions, immediately after consumption in the exposure sessions, and 1-hour after the exposure sessions. In each of these analyses, Exposure Session (1, 2, 3, 4) was the within-subject factor, and Drink Exposure Condition (LED-U, LED-S, HED-U, HED-S) was the between-subject factor. Learned satiety would suggest that hunger ratings taken after consumption at each exposure session would progressively decrease over the course of the four exposures, for the HED conditions.

Initial Hunger Ratings

Hunger ratings taken at the start of each exposure session (see Figure 5.22) did not differ significantly, either between Exposure Sessions ($F(3, 132)=1.08$, $p=.359$) or between Drink Exposure Conditions ($F(3, 44)=0.10$, $p=.960$), and the interaction between session and condition did not reach significance ($F(9, 132)=1.21$, $p=.296$), indicating that ratings of hunger across exposure sessions did not differ between the exposure conditions.

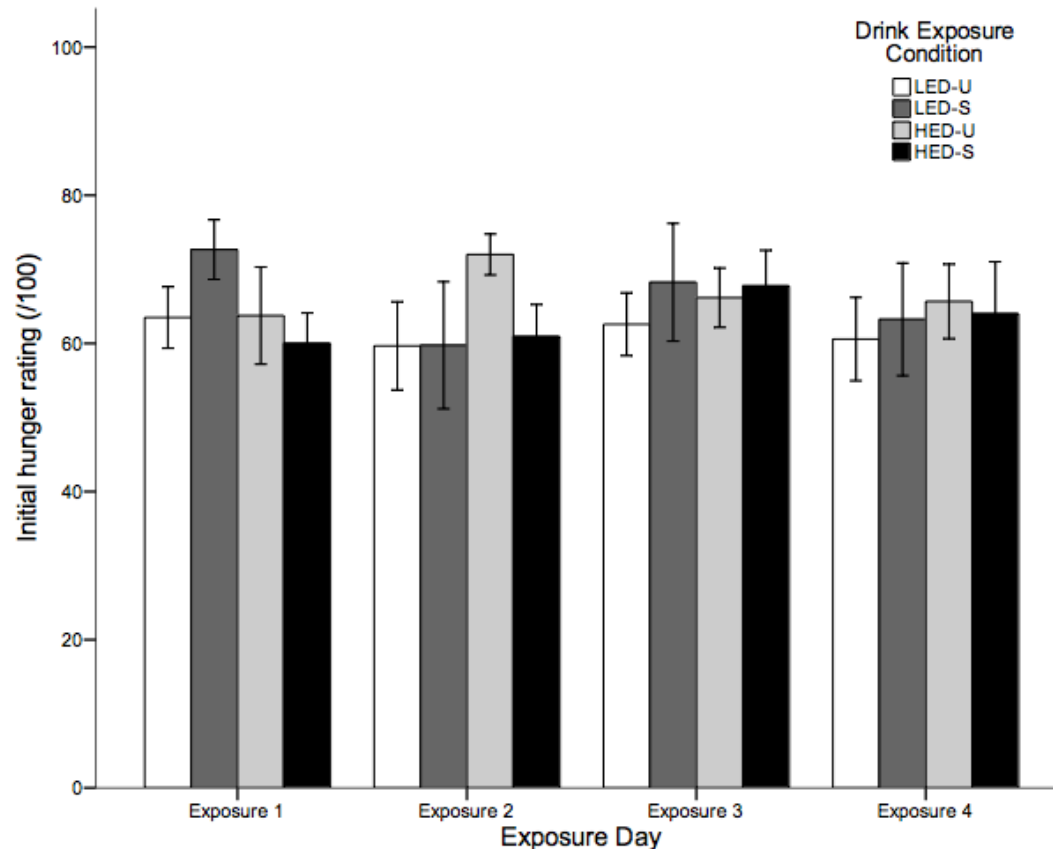


Figure 5.22: Initial hunger ratings for each exposure condition at the start of each exposure session in Experiment 6

Post-Consumption Hunger Ratings

Hunger ratings taken immediately after consumption of the exposure drink at each exposure session (see Figure 5.23) did not differ significantly, either between Exposure Sessions ($F(3, 132)=0.48$, $p=.698$) or between Drink Exposure Conditions ($F(3, 44)=0.32$, $p=.809$), and the interaction between session and condition did not reach significance ($F(9, 132)=0.98$, $p=.462$), indicating that ratings of hunger across exposure sessions did not differ between the exposure conditions.

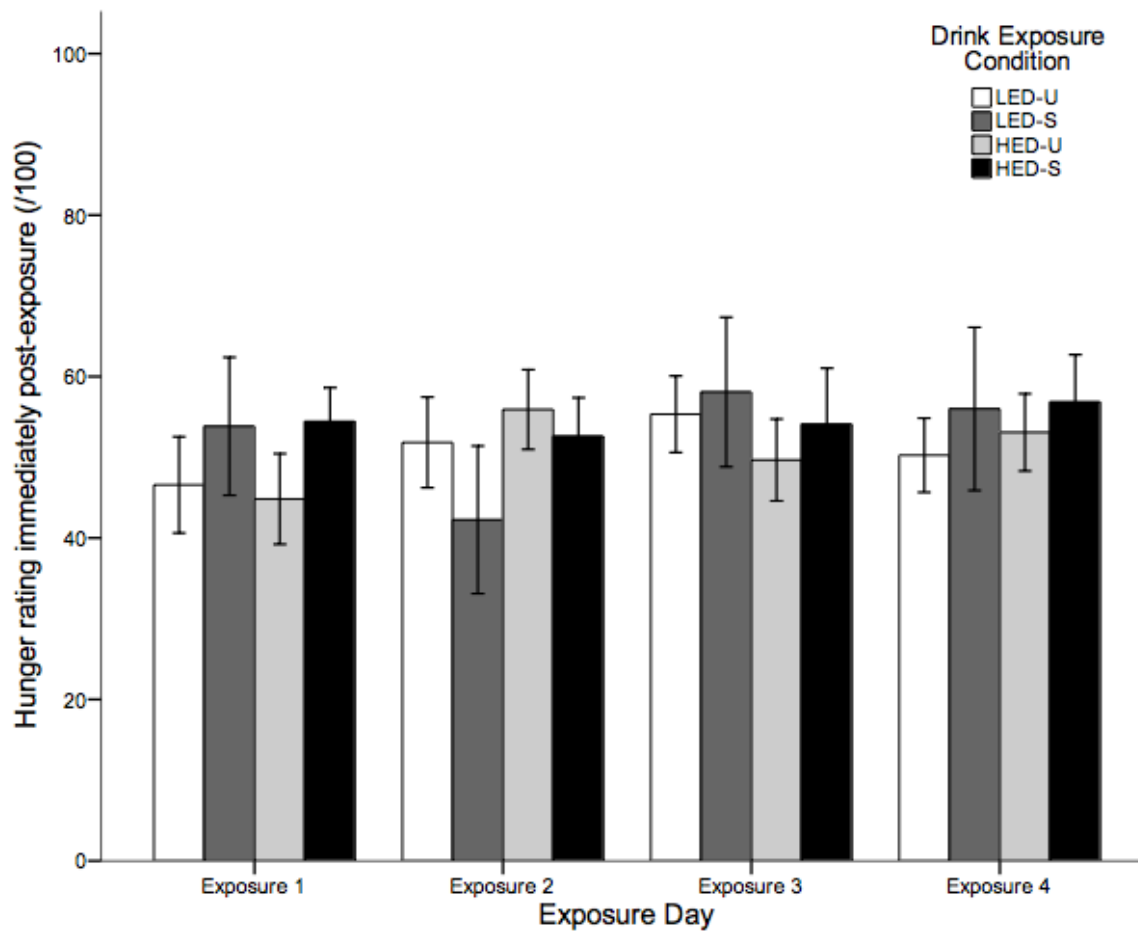


Figure 5.23: Hunger ratings for each exposure condition taken immediately after each exposure session in Experiment 6.

1-Hour Post-Consumption Hunger Ratings

In this analysis, hunger ratings between Exposure sessions failed to meet the assumption of Sphericity (Mauchly's $W(5)=.65$, $p=.003$), so the following statistics are reported with the Greenhouse-Geisser adjustment, where applicable. Hunger ratings taken 1-hour post-consumption at each Exposure Session (see Figure 5.24) did not differ significantly, either between Exposure Sessions ($F(2.39, 102.90)=1.618$, $p=.198$) or between Drink Exposure Conditions ($F(3, 43)=2.25$, $p=.096$), and the interaction between session and condition did not reach significance ($F(7.18, 102.90)=0.93$, $p=.490$), indicating that ratings of hunger across exposure sessions did not differ between the exposure conditions.

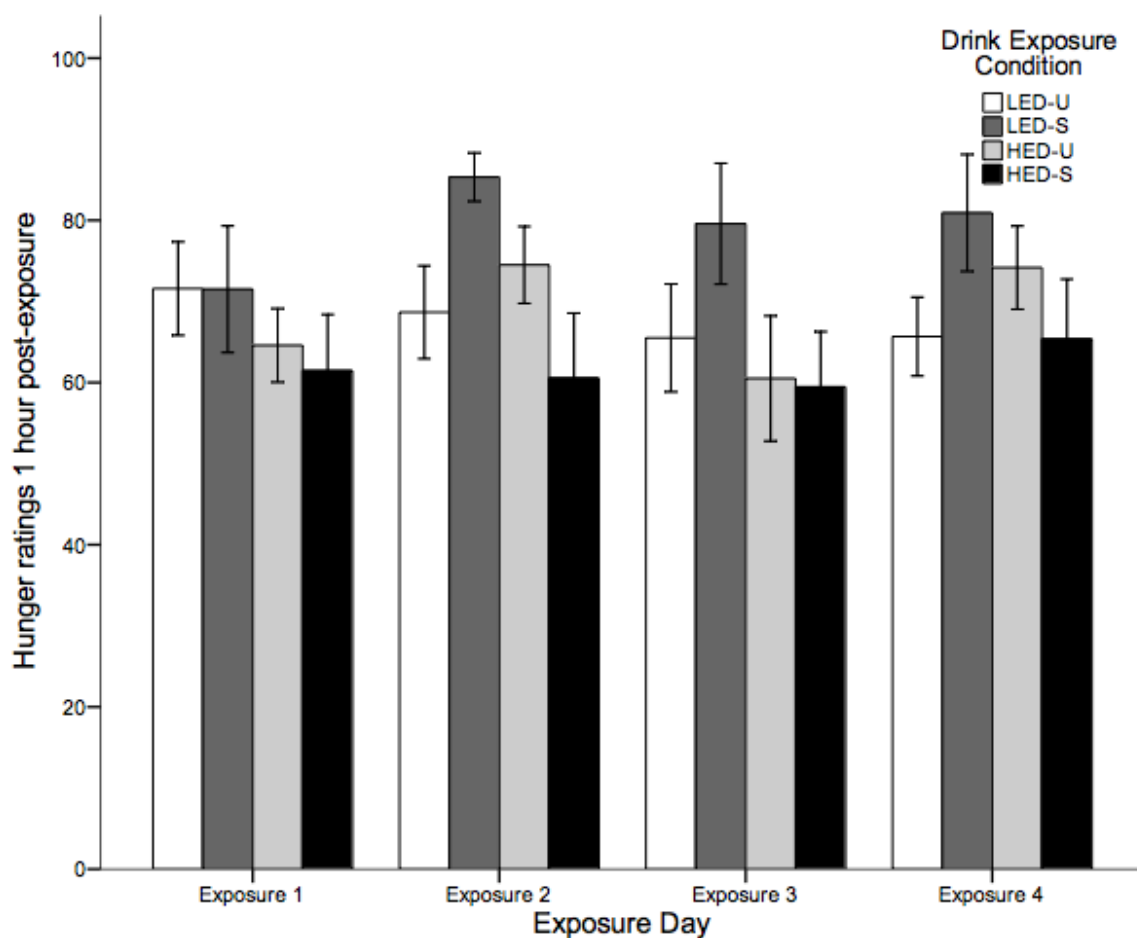


Figure 5.24: Hunger ratings for each exposure condition 1 hour after each exposure session in Experiment 6.

Hunger ratings for all three time-points (pre-exposure, immediately post-exposure, and 1-hour post-exposure) show no evidence of learned satiety, nor significant differences between Exposure Drink Conditions.

5.3.4. Exp. 6 Discussion

This final experiment of the thesis set out to determine if long-term changes to pleasantness ratings, as a consequence of Flavour-Flavour Learning (FFL) and Flavour-Consequence Learning (FCL), affect the magnitude of consumption-related pleasantness and subsequent sensory-specific satiety. A novel flavour was paired with beverages in the exposure sessions, and the same flavour was presented in a jelly in SSS test sessions. This manipulation was designed to test whether learned associations acquired in one context (that of a drink), are expressed in a different context (a snack food) when the conditioned stimulus is the same. This paradigm has previously been employed to demonstrate transference of learned liking for the CS flavour from acquisition with liquid stimuli (beverages) to expression with a solid stimulus (sorbet) (Yeomans, Gould, Bertenshaw, et al., 2009; Yeomans, Leitch, et al., 2008), and in fact this experiment used the same drinks.

The findings produced no evidence that SSS had occurred on either of the SSS test days, baseline pleasantness ratings for both the low- and high-energy versions of the food did not change during the course of the experiment, and these results did not differ between exposure conditions. The dearth of SSS evidence from pleasantness-change ratings was also reflected in Desire To Eat (DTE) ratings throughout. Some researchers (e.g. Berridge, 1996; Mela, 2001; Rogers, 1990) have suggested that SSS is a reflection of change in willingness to consume a food ('wanting'), rather than change in pleasantness ('liking') for the food. However, the agreement between ratings of pleasantness and DTE in this experiment instead support recent work by Havermans, Janssen, *et al* (2009), which provides evidence that the two measures are equally effective at determining SSS (see Section 1.2.1.3: Critique of Sensory-Specific Satiety).

This experiment failed to provide evidence of any of the phenomena under scrutiny: SSS was absent from the results, and learned liking was neither acquired, nor expressed in this experiment. Analysis of baseline ratings of the SSS test foods showed that the Uneaten Marshmallow was rated more pleasant than both the Eaten Jelly and the Uneaten Ryvita, and novelty ratings for the Ryvita were greater than those for the Jelly and Marshmallow, though neither of these variable differed between the HED and LED groups. Results from the pilot testing suggest the jelly test food was not equally matched to the drink in liking, though mean pleasantness ratings at that stage differed by only 5 points on the 100-point

scale. This version of the jelly was selected as the test food based on the results of pilot testing. Although it was not rated high on pleasantness, it was the best match to the drinks. Baseline rated pleasantness of the Jelly on the first SSS test day was also quite low, varying from around 180 to 280 between experimental conditions. It could be construed that to some extent both the drink and the jelly were at risk of a floor-effect: with pleasantness ratings at just below the mid-way mark on the scale. However, all scales in these experiments were presented as unipolar, and therefore a low pleasantness rating does not equate necessarily to dislike, but rather probably equates to neutrality. This may come down to individual differences in interpretation of the unipolar scales - it is quite possible that some participants may have intended lower ratings of pleasantness to correspond with dislike. Nevertheless, the Jelly was rated least pleasant of the three foods presented during testing, and significantly so in comparison to the Marshmallow. Therefore a floor-effect may well have restricted any expression of SSS, as further decline in pleasantness during consumption may have been undetectable.

In retrospect, it was a methodological error to stick to the 50g portion size of the Eaten food for the jelly – hindsight indicates that if oral exposure is a greater predictor of SSS than quantity, then a jelly-like food that melts at room temperature (and therefore will certainly do so at body temperature in the mouth) might require a larger portion to induce SSS. This confound alone however is insufficient to explain the lack of evidence of either learned satiety, or flavour-based learning found in this study – especially as the stimuli had been used in previous experiments to generate these phenomena successfully. One explanation of this null result might be that the flavour of the jelly was not as closely related to the flavour of the drinks as expected. There may be an argument for using sorbet instead, as the frozen food may have reduced the intensity of flavour, and perhaps masked any obvious sensory differences between the food and the drinks in a way that could not be achieved with the Jelly.

5.4. General Discussion of Experiments 5 and 6

After the methodological studies in Chapter 4, the two experiments presented in this chapter returned to the original aims of the research conducted for this thesis: to establish the effects of long-term hedonic changes arising from dietary learning on the magnitude of sensory-specific satiety. SSS is generally explained in terms of habituation to the sensory properties of the Eaten food, and to the extent that the Eaten and Uneaten foods share sensory properties, pleasantness decline may transfer to a similar Uneaten food (see Section 1.2.1.1: Sensory-Specific Satiety in Humans). Hedonic valence transfer has also been observed in flavour-based learning where repeated exposure to the conditioned stimulus is reinforced, as is the case in flavour-flavour (FFL) and flavour-consequence learning (FCL) (see Section 1.3.3.1: Flavour-Based Learning). Novel food stimuli are more susceptible to changes in pleasantness both in the absence of reinforcement (e.g. mere exposure effects Zajonc, 1968 see Section 1.3.1.1: Mere Exposure) and in the presence of reinforcement (see Section 1.3.3.1: Flavour-Based Learning). Mere exposure is itself a prerequisite of learning, and although reinforcement may be unintended, is practically impossible to ensure that spurious associations are not formed during such exposure, as associations may be made with environmental and contextual aspects of the situation in which the food is consumed, as well as with the sensory aspects of the food. Therefore prior learning may contribute to the consumption-related pleasantness decline that results in SSS, and would be much easier to detect with a novel food CS that was not already subject to learned associations, in a dietary learning paradigm.

Experiment 5 set out to measure the effect of FCL and learned satiety and Experiment 6 to measure the effect of FFL and FCL, on the extent to which SSS develops. In Experiment 6 the CS was a novel jelly/blancmange snack developed in high- (HED) and low-energy (LED) densities, and the LED version was presented as the Eaten food in SSS tests at the start, after four, and after eight exposures. In Experiment 6 the conditioned stimulus (CS) was a novel-flavoured drink, and was created in four versions that resulted in pairings of the CS with either sweetness; energy; sweetness and energy; or neither sweetness nor energy. SSS tests were conducted before and after four exposures to the drink. The Eaten food presented in the SSS tests was a jelly made from the low-energy unsweetened version of the exposure beverage.

Neither Experiment 5 nor Experiment 6 provided any evidence of dietary learning – either flavour-based (FFL, FCL), or learned satiety. SSS was detected only on test day 1 in Experiment 5, with subsequent test days and those in Experiment 2 demonstrating no differential decline in pleasantness between the Eaten and Uneaten foods. However, in review it is likely that neither of these Experiments was an adequate test of dietary learning, due to methodological issues, and the Eaten food in Experiment 6 may have been presented in a portion too small to induce SSS. Thus there is insufficient evidence here to conclude that dietary learning does, or does not, influence the magnitude to which SSS develops.

Disappointing as these findings may be, a number of insights on methodology can be gained from these experiments. Firstly, baseline ratings of pleasantness and novelty were not equal across the SSS test foods, and this is important, especially as results from Experiment 4 suggest that both these variables can be significant factors in the development of consumption-related pleasantness decline (see Section 4.4.4: Exp. 4 Discussion). The issue of pleasantness ratings may be inflated by confusion arising as a result of the unipolar scales employed in these experiments being interpreted as bipolar scales. For example, low pleasantness ratings may be intended, from the participant's perspective, to indicate a dislike for the food. However, Such ratings are interpreted for analysis simply as low-pleasantness, rather than dislike. In the experiments presented here, interpretation of the VAS may have confounded the findings, but regardless of this possibility it was still apparent that the Eaten food was in some instances disliked sufficiently to put off consumption of the food, and to cause the participants to withdraw from the study for this reason.

There is some evidence that participants were able to detect differences between the high- and low-energy versions of the test foods, and this presents a possible confound to assumptions of hedonic transference. Learning is expressed in relation to the CS (see Section 1.3.3.1: Flavour-Based Learning), and if the snack presented in SSS tests appeared different from those consumed in exposure sessions (as was the case with HED conditions), then it is reasonable to assume that if learning had been acquired, it may not have been measured under these conditions. For this reason, and those given above regarding baseline rated pleasantness and novelty, more attention must be invested in development and piloting of novel test foods to ensure not only that pleasantness and novelty ratings in a larger sample are realistic, but also that matching for flavour and taste properties is carefully ascertained.

It is possible that in Experiment 6, the 50g portion of the Eaten food in SSS tests was insufficient to allow SSS to develop. The Jelly snack melted at room temperature, and would therefore do so in the mouth during consumption. Oral exposure is a strong predictor of SSS (see Section 1.2.1.1: Sensory-Specific Satiety in Humans), and 50g of a melting Jelly is unlikely to provide sufficient sensory information from which pleasantness decline in SSS may be derived.

Thus, these experiments have proved useful in characterising the development of SSS in a snack context, and some of these issues are revisited in the General Discussion (see Chapter 6: General Discussion).

CHAPTER 6: General Discussion

Sensory-specific satiety is a short-term consumption-related pleasantness decline that is greater for consumed (Eaten) foods than unconsumed (Uneaten) foods. This thesis set out to determine the extent to which SSS may be subject to modulation by long-term hedonic changes, specifically those induced by mere exposure, monotony, flavour-based learning and learned satiety. During the process of researching the thesis, the work also came to represent an exploration of SSS testing methods and procedures, and their implications for the way pleasantness decline is expressed in a laboratory situation. Six experiments were conducted in Chapters 3, 4 and 5 (see Chapter 2: General Methods for the chronology), and the remainder of this chapter provides an overview of the findings and their theoretical implications; an exploration of the shortcomings of these studies; and the implications for future investigations.

6.1. Summary of Findings

An overview of the experimental findings follows, organised thematically to assist with interpretation of the work as a whole. In this section the findings are compared to findings from the relevant literature. The implications of these findings are further discussed in a broader context in Section 6.2: Theoretical Implications of the Present Work.

6.1.1. Mere Exposure and Monotony

In Experiment 1, participants were exposed daily to the same snack food for 13 days in a home-consumption model (see Section 3.1: Experiment 1). Hedonic ratings of the exposure food before and after exposure were compared to ascertain whether mere exposure (an increase in ratings) or monotony (a decrease in ratings) took place. The results showed no discernible effect of multiple exposures on either hedonic or novelty ratings of the exposure foods, and therefore a negative result for both Monotony and Mere Exposure. This finding contrasts with those of other research in this area where mere exposure is measured as elevated liking (e.g. Pliner, 1982; Stevenson & Yeomans, 1995; Zajonc, 1968; see Section 1.3.1.1: Mere Exposure), and monotony measured as declined liking (e.g. Hetherington, et al., 2002; Meiselman, et al., 2000; Weenen, et al., 2005; see Section 1.3.1.2: Monotony).

The literature points to novelty as a significant factor in exposure: novel foods are subject to greater mere exposure effects than familiar foods (e.g. Crandall, 1985; Pliner, 1982; Stevenson & Yeomans, 1995). Findings from Experiment 1 suggest that although the test snacks were not deemed unpleasant (mean ratings all above the midpoint on the rating scale), they may have been insufficiently novel (nearly all ratings below the midpoint on the scale) at the start of the experiment to exhibit detectable effects of Mere Exposure and Monotony. This result is in agreement with Zajonc (1968), who reports a log-linear relationship between frequency of exposures and the effect of mere exposure. In essence, the more familiar the stimulus, the greater the number of (non-reinforced) exposures required to exert influence on the attitude towards the stimulus. It is reasonable to infer that the fairly low baseline novelty ratings for the foods in Experiment 1 are an indication of familiarity with one or more of the sensory properties of the test foods, and therefore an indication that the foods' potential vulnerability to the effects of mere exposure was attenuated.

6.1.2. Dietary Learning

Two experiments endeavoured to precipitate dietary learning and both failed to provide evidence of success. In Experiments 5, participants consumed 200g of either a high- (HED) or low-energy (LED) version of a novel blancmange-like sweet food on eight non-consecutive days. In Experiment 6, participants consumed 400g of one of four versions of a beverage that differed on two axes (sweet vs. unsweetened; HED vs. LED) on four non-consecutive days.

In contrast to the exposure sessions in Experiment 1, where care was taken to ensure the absence of experimental-induced reinforcement, these experiments were intended to create differences in attitude towards the stimuli on the basis of the reinforcing properties of sweetness and post-ingestive energy delivery. Flavour-flavour learning (FFL), flavour-consequence learning (FCL) and learned satiety were expected to escalate baseline pleasantness ratings through exposures (see Section 1.3.3.1: Flavour-Based Learning). Pairing of a novel CS with either a known (and liked) sensory stimulus (e.g. sweetness or a liked flavour), or a positive consequence of consumption (e.g. energy or caffeine delivery) will result in transference of the hedonic valence from the UCS to the CS. In contrast to published research (e.g. Brunstrom, et al., 2005; Chambers, et al., 2007; Tinley, et al., 2003; Yeomans, Durlach, et al., 2005), these experiments failed to show significant differences between pre- and post-exposure ratings of pleasantness, and

therefore presented a null result for both flavour-flavour and flavour-consequence learning. These studies also failed to yield evidence of learned satiety as first demonstrated by Booth (1972), which manifests as a learned control over meal size and intake (see Section 1.3.3.2: Learned Satiety), based on an individual's ability to predict the satiating power of a food stimulus, in turn founded upon prior learned associations. It was expected that learned satiety may manifest in these experiments as changes to hunger ratings over the course of the exposures, which would indicate a learned association between the sensory aspects of the food and the satiating effect of consumption (e.g. Yeomans, Weinberg, et al., 2005) – in essence revealing anticipated satiety – but no such evidence was generated.

6.1.3. Influence of Long-term Changes in Food Pleasantness

The findings from Experiments 1, 5 and 6 show no evidence that the experimental designs sufficiently precipitated any form of long-term change in liking for the test foods as a result of repeated exposure. The results from Experiment 1 suggest that multiple home-consumption exposures may reinforce sensory-specific satiety, and that exposure to the placebo snack or no exposure is resistant to SSS. However, the control groups showed no evidence of SSS at baseline - on test day one - and so the negative result for SSS on the post-exposure test day is neither surprising, nor indicative of exposure effects, as neither of the control groups were exposed to test foods. These findings support those of Hetherington *et al* (2000), where a differential effect of multiple exposures on pleasantness ratings was observed (chocolate declined in rated pleasantness after multiple exposures, but french fries did not), and yet sensory-specific satiety was unaffected by the exposures. Overall, evidence for mere exposure, monotony and dietary learning was not found, and interpretation of the findings was further obscured by an absence of SSS in Experiment 6, and in the latter test days of Experiment 5 (see Figure 6.1: Summary of Findings for Sensory-Specific Satiety).

6.1.4. Sensory-Specific Satiety

Sensory-specific satiety is operationalised as a statistically significantly greater decline in rated pleasantness for a food that is consumed (Eaten), than for foods tasted but not consumed (Uneaten) (e.g. Hetherington *et al.*, 1989; Johnson & Vickers, 1992; Johnson & Vickers, 1993; Miller *et al.*, 2000; Raynor & Wing, 2006; B. J. Rolls *et al.*, 1988b; B. J. Rolls *et al.*, 1981; E. T. Rolls *et al.*, 1983). As discussed in Section 2.1: Methodology and

Measurement of SSS in the Literature, SSS is defined by the methods used to test for it. Uneaten foods may also decline in rated pleasantness after consumption of the Eaten food, usually to the extent that the Uneaten food(s) share similar sensory properties with the Eaten food (see Section 1.2.1.1: Sensory-Specific Satiety in Humans). Such transfer effects are often observed for foods similar in taste, such as sweet or savoury; or texture such as a cereal bar or potato crisps (e.g. Guinard & Brun, 1998; Johnson & Vickers, 1993; B. J. Rolls, et al., 1981; B. J. Rolls, et al., 1984).

Evidence of sensory-specific satiety and transfer effects were found in some experiments but not in others: Table 6.1 provides a summary of these findings.

Table 6.1: Summary of findings for Sensory-Specific Satiety

Experiment	Evidence of SSS	Transfer Effects	Eaten Foods
1 Pre-exposure	✓ experimental groups ✗ control groups	✗ experimental groups ✓ control groups	Chocolate Bar / Cereal Bar
Post-exposure	✓ experimental groups ✗ control groups	✗ experimental groups ✓ control groups	
2 Single test	✓ all groups (with Uneaten foods for comparison)	✗ none found	Marshmallow / Apple Chips
3 Single test	✗ all groups (with Uneaten foods for comparison)	✗ none found	Crackers / Rice Cakes / Pretzels
4 Single test	✓ 1-contrast groups ✗ 4-contrast groups	✗ 1-contrast groups ✗ 4-contrast groups	Mini Ryvita / Cereal Bar
5 Pre-exposure	✓ whole sample	✓ whole sample	LED dessert snack
Mid-exposures	✗ whole sample	✗ whole sample	
Post-exposures	✗ whole sample	✗ whole sample	
6 Pre-exposure	✗ whole sample	✗ whole sample	LED Jelly snack
Post-exposure	✗ whole sample	✗ whole sample	

Findings from Experiment 1 indicate that SSS can successfully be observed with only one Uneaten food for comparison. In this study both foods were sweet, and therefore the Eaten food was to a certain extent vulnerable to transfer effects. Intriguingly, SSS was a significant finding for the sample as a whole on both days, and yet was observed specifically in the experimental conditions only. To recap, participants were exposed to a test food on 13 consecutive days: experimental conditions consumed either the Eaten or the Uneaten foods during the exposure phase; control conditions consumed either a third savoury snack (not otherwise used in the experiment), or were not exposed to any snack food during the exposure phase. The control conditions showed no effect of SSS on test

days, instead exhibiting clear transfer effects, with both Eaten and Uneaten foods showing similar decline in rated pleasantness.

Interpretation of these results however should consider the experimental design. With only one Uneaten comparison food, the failure to observe significant differences in changes to rated pleasantness between the two foods is by default a positive result for a transfer effect, given that both foods were sweet snacks presented for consumption in the form of a bar. The design of this experiment causes a confound in itself, in that it presents possible outcomes as binary: either the analysis will indicate SSS, or it will indicate transfer effects. There is no scope for positive, nor null results to be presented for both phenomena concurrently. Hence caution should be used when interpreting the transfer effect (and indeed the occurrence of SSS) in Experiment 1: presentation of a second Uneaten food that was not sweet would have provided a more secure foundation for comparison, and to test more clearly for both SSS and transfer effects.

Experiments 2, 3 and 4 represent a sequence of studies that test SSS on a single occasion, and each presents diverse results in terms of SSS and transfer effects. Experiment 2 revealed evidence of SSS for all experimental conditions that included an Uneaten food component. In Experiment 3 the findings were reversed: all experimental conditions with an Uneaten food component failed to find evidence of SSS. However, Experiment 3 was ultimately underpowered (see Section 4.3.1: Exp. 3 Background), and results should not be construed as reliable. Transfer effects were not apparent in either of these studies. Findings from Experiment 4 presented a similar pattern to those of Experiment 1 in that the one-contrast conditions exhibited sensory-specific satiety, but no transfer effect. In this instance however, the Eaten foods varied in taste (sweet vs. savoury), and the Uneaten food was either 'matched' or 'opposed' to the Eaten food on this axis. Thus this study provided an opportunity to differentiate SSS (predicted to be greater with opposing foods) from transfer effects (predicted for matched foods). These predictions were not supported by the findings, but the design created many experimental sub-conditions, reducing sample size and therefore statistical power with each level of granularity in the analysis. The four-contrasts conditions exhibited neither SSS nor transfer effects.

The final two experiments returned to testing SSS in multiple instances, three times in Experiment 5, and twice in Experiment 6. Test foods for both were developed in the laboratory - a blancmange-like snack and a novel-flavoured jelly respectively. Only Experiment 5 provided evidence of statistically significant SSS, and only on the first test

day, with the whole sample aggregated. The remaining two tests days in Experiment 5 and the two in Experiment 6 failed to yield SSS, and the best explanation for this lies with the Eaten food, in that the 50g portion size was likely inadequate to allow sensory differentiation during the consumption phase (discussed in more detail in Section 6.3.3: Methodological Issues).

Uniquely in all these experiments, Experiment 5 test day one findings showed manifestation of SSS and transfer effects concurrently. Such positive results among so many negative findings would appear to indicate that in this instance, the Eaten and Uneaten Sweet foods were sufficiently similar to observe hedonic transfer from Eaten to Uneaten food, *and* that the Eaten and Uneaten Savoury foods were sufficiently different to allow observation of greater pleasantness decline for the former than the latter. At baseline, the Eaten food was rated lowest for pleasantness, and highest for novelty in this experiment. The findings suggest that the potential for a floor effect on SSS incurred by low pleasantness ratings may have been mitigated by the highly-rated novelty of the test food. The absence of these findings in the second and final test days of the same experiment may therefore be interpreted as a result of decline in novelty after four and eight exposures respectively. Taken together, these findings suggest that the baseline test in Experiment 5 provides strong evidence of the ideal conditions under which SSS can be observed, and this is discussed further in Section 6.4: Implications of the Present Work for Future Research.

Overall, sensory-specific satiety was neither a reliable nor a robust finding in these experiments. The use of pleasantness ratings data to assess SSS, is however still valid (see Section 1.2.1.3: Critique of Sensory-Specific Satiety). Where 'Desire To Eat' (DTE) scales were used, the ratings were parallel with those of pleasantness of the food. This lends weight to the notion that pleasantness ratings may be measuring aspects of both wanting and liking (Mela, 2001), and that SSS manifests as a decline in both variables (Havermans, Janssen, et al., 2009). Although the findings support Berridge's (1996) assertion that many studies equate selection and consumption of food to 'wanting', when perhaps this is not strictly correct given the meaning of the word in this context, nevertheless there is evidence here that SSS is a phenomenon of interest when observing declining pleasantness of foods during consumption. Under some circumstances SSS may be elusive, but there is sufficient evidence here to dismiss any claim that it is an epiphenomenon.

Overall in the research in this thesis, negative results for SSS have coincided with discoveries regarding the nature of SSS, its sensitivity to variations in experimental methodology and procedure (discussed in Section 6.3: Shortcomings and Limitations of the Present Work), and the circumstances which give rise to optimum pleasantness decline of the Eaten food (outlined in Section 6.4: Implications of the Present Work for Future Research).

6.1.5. Number and Type of Uneaten, Contrasting Foods and Sensory-Specific Satiety

Findings from Experiment 1 suggested the Uneaten food component in SSS testing may have revealed a cognitive component of SSS, effectively a loss of interest in the Eaten food based upon the expectation of consuming other foods. Experiments 2, 3 and 4 addressed the procedural aspects of sensory-specific satiety, the aims of which were to establish the effects of Uneaten foods on the magnitude of SSS (see Chapter 4: The Role of Uneaten Foods in Sensory-Specific Satiety). In each of these studies, the Uneaten foods varied in number and taste (sweet vs. savoury), while the Eaten food remained static in Experiments 2 and 3 (sweet and savoury respectively). In Experiment 3, the additional axis of taste was introduced for the Eaten food so that it was either sweet or savoury.

Findings from Experiment 2 show strong evidence for greater decline in rated pleasantness for the Eaten food with each additional Uneaten food presented, and optimum decline was achieved with two Uneaten foods, one sweet and one savoury. Although Experiments 3 and 4 did not replicate this finding, neither did they yield reliable evidence of statistically significant SSS (with the exception of the one-contrast condition in Experiment 4), and this makes interpretation of the null results for the effect of the Uneaten foods problematic. In addition, a significant consumption-related pleasantness decline for the Eaten food in the absence of Uneaten contrasts was present in Experiment 2, but not in Experiment 3 or 4.

Further complications arose from these two experiments, for example Experiment 3 was ultimately underpowered (as discussed in Section 4.3.1: Exp. 3 Background). Furthermore, both studies included Eaten foods that were rated quite low in pleasantness, and some participants reported difficulty consuming the entire portion in the consumption phase. In conjunction with, and in the light of these methodological issues (discussed further in Section 6.3.3: Methodological Issues), Experiment 4 contained a potential design flaw because the Eaten foods were not counterbalanced: only the Cereal bar (sweet) and mini Ryvitas (savoury) were presented in the consumption phase. A further possible flaw in the design of the latter two of these experiments is that neither included the two-contrast (one sweet, one savoury) condition that demonstrated the optimum pleasantness decline in Experiment 2. This was unavoidable in Experiment 3 as the design was inherited from an apparently successful experiment in the same laboratory, and weaknesses in the data were not discovered until Experiment 4 was in

progress. In hindsight, Experiment 4 should have included the two-contrast (sweet and savoury) condition alongside, or at the expense of, one of the other experimental conditions, but this opportunity was overlooked at the time.

The published literature presenting successful experimentally-induced SSS have used multiple Uneaten foods: e.g. between seven and nine (Hetherington, et al., 2000; Hetherington, et al., 1989; Johnson & Vickers, 1992; B. J. Rolls, Hetherington, et al., 1988b); and up to twelve (Vandewater & Vickers, 1996). Other studies have succeeded with fewer Uneaten foods, for example between three and five (B. J. Rolls & McDermott, 1991; Snoek, et al., 2004; Vandewater & Vickers, 1996). Only two studies stand out as using a single Uneaten food in SSS experimentation (Havermans, Janssen, et al., 2009; Smeets & Westerterp-Plantenga, 2006), suggesting that findings for SSS are more difficult to obtain with fewer contrasting foods. The increase in magnitude of pleasantness decline in Experiment 2 was clearly related to the addition of further Uneaten foods presented in the pre- and post-consumption phases of SSS testing, which supports the hypothesis that the presence of unconsumed foods augments the extent to which sensory-specific satiety develops in an experimental context. With all else held constant, the linear effect of Uneaten foods points to a cognitive component of sensory-specific satiety. This explanation goes some way to explaining the difficulties in evoking statistically significant SSS in situations where there are few Uneaten foods for comparison.

6.2. Theoretical Implications of the Present Work

What then has the outcome of the studies in this thesis contributed to our fundamental understanding of the nature of sensory-specific satiety? The following sections examine the implications of the present work in the broader context of theoretical mechanisms of sensory-specific satiety.

6.2.1. The Fundamental Nature of Sensory-Specific Satiety

As discussed at the start of the thesis (see Section 1.2.3: Putative Mechanisms for Sensory-Specific Satiety), the most commonly cited mechanism of sensory-specific satiety is that of ‘sensory fatigue’ experienced by the consumer, and leading to cessation of consumption (Hetherington, 1996). Note that the concept of fatigue in this context is not a loss of ability to detect the sensory experience of the ingested food, but rather a decline in hedonic response to that sensory input, most commonly interpreted as ‘hedonic habituation’ (see Raynor & Epstein, 2001). There is evidence in the earlier literature for patterns of neuronal habituation in the prefrontal cortex in relation to SSS (Kringelbach, 2000; E.T. Rolls, 2005; E. T. Rolls et al., 1986). The neurons reduce firing frequency in line with consumption, suggesting that the termination of a discrete eating episode is correlated with habituation to the sensory properties of the food being consumed. The cells resume activity to normal levels once a new food is provided – thus strong evidence of habituation and dishabituation, in conjunction with changes in observed feeding behaviour shows that SSS may occur at a neuronal level. The Theory here is that hedonic decline during consumption eventually leads to cessation of ingesting the food to which the organism has become habituated.

In contrast to the earlier literature, the majority of recent studies have failed to find evidence of SSS dishabituation in humans. Findings from one recent study (Brondel et al., 2009) demonstrated that an Eaten food already consumed to satiety continued to be ingested if small changes are made to the sensory aspects and variability of the meal. In this instance the added option of tomato ketchup to accompany fries meant that the hedonic decline for the fries was partially reversed by the addition of the condiment in a successive session. Brondel et al. (2009) interpret the findings as a partial disruption to SSS, and also as a demonstration of a dishabituation response, triggered by the change in the sensory properties of the Eaten food. Indeed, the results showed a small recovery of

SSS for the condition that received the condiment successively, and this attenuation of hedonic decline for the Eaten food was not observed in the control group for whom the meal was not varied. The third condition (received condiments and the fries simultaneously) also consumed more than the control group, suggesting that the presence of the condiment at the outset of consumption was sufficient to exert an influence on SSS – a factor that is important when re-examining the results of Experiments 2, 3 and 4 of the present work. The design of the Brondel et al (2009) study allows for the possibility of a cognitive (expectancy) element as a factor in SSS, which is not adequately explained by dishabituation.

Epstein, Temple, Roemmich, & Bouton, (2009), in a review of the habituation literature and theory, point out that SSS and habituation are measured with different experimental methods, and that habituation may be an explanation of SSS, but the terms are not interchangeable. Epstein et al (2009) go further to state that dishabituation is impossible to infer from SSS data if any of the Uneaten foods are tasted and rated before the Eaten food in the post-consumption phase of experimentation. In most SSS studies the pre-consumption and post-consumption foods are usually presented in a randomized order for each participant, thus the question of dishabituation had not been adequately tested. Havermans, Siep & Jansen (2010) addressed this gap in the literature, and found that the magnitude of SSS was not sensitive to a brief interruption to taste and rate Uneaten foods. In this study the presentation of post-consumption foods for rating deviated from the standard SSS paradigm in that they were presented serially rather than all together. In addition, the presentation of the post-consumption foods was manipulated so that the Eaten food was tasted either first (i.e. without interruption) or last (interruption to taste other foods). If SSS were due to habituation, then dishabituation would have occurred in the interruption condition. However, the tasting of alternate foods did not 'reset' the declined hedonic response to the Eaten food, suggesting that SSS recovers over time spontaneously, and not as a dishabituation response induced by tasting other foods. Extending the investigation, Havermans (2012) had one group consume a second (Eaten) food after the first, in a second consumption phase, before completing the post-consumption phase of tasting and rating all the foods. If SSS were subject to dishabituation, we would expect it to manifest as a recovery of SSS for the first Eaten food after consuming the second Eaten food. No such result was found, and in fact both the Eaten foods were subject to similar magnitude of SSS in the usual comparison with Uneaten foods.

So far, this newer evidence suggests SSS to be a food-specific hedonic response decline that is resistant to modulation (or dishabituation) by either tasting other foods post-consumption or consumption of a second Eaten food. Thus, hedonic habituation would appear to be an incomplete model of the mechanism(s) underlying SSS. However, the findings from Experiment 2 (see Section 4.2.4: Exp 2. Discussion) show evidence that the manipulation of the Uneaten foods does affect the degree to which SSS develops. The results of this experiment suggest a potential cognitive component to SSS (see Section 6.1.5: Number and Type of Uneaten, Contrasting Foods and Sensory-Specific Satiety) that is entirely unrelated to the Eaten food. The possibility of a cognitive contribution to the development of SSS was not allowed for in the Havermans (2010, 2012) studies - within each of the experiments the Uneaten foods remained static in number. The serial presentation of post-consumption tasting foods does not preclude the potential for cognitive expectations induced by the presentation of the pre-consumption tasting foods.

It appears then that hedonic habituation is most useful as an explanation of the decline in pleasantness of the Eaten food, separate from the effects of Uneaten foods, rather than an explanation of SSS in its entirety. Furthermore, it is food-specific in nature (as evidenced by the Havermans experiments), and the pleasantness decline for the particular test food may still be caused by habituation. As Havermans (2012) suggests, that SSS doesn't appear to be subject to dishabituation is not conclusive evidence that there is no underlying habituation in its development.

Given the recent literature and the findings in this thesis, I suggest that the consumption-related pleasantness decline of the Eaten food represents a baseline of sorts that may be subject to alteration by cognitive factors. Beyond this baseline for the Eaten food, further change to pleasantness ratings may occur as a direct consequence of the apparent availability of alternative (Uneaten) foods presented during testing, and may be responsive to the similarity (or difference) in sensory properties between the unconsumed foods and the Eaten food. The cognitive component may manifest in subjective experience as expectancy or anticipation.

From a theoretical perspective then, SSS could be composed of multiple mechanisms that contribute to the whole – two of which are identified here – and this would go some way to accounting for contrast effects and some results from the studies in this theses. Firstly, hedonic habituation to the Eaten food (without sensory contrast) was observed in all experiments that used the no-contrast condition (Experiments 2, 3 and 4), measured by a

significant decline in rated pleasantness between pre- and post-consumption phases in the SSS test. Secondly, Experiment 2 provides evidence of varied pleasantness decline for the Eaten food when manipulations are applied to the number and type of Uneaten foods. Contrast effects may attenuate or bolster hedonic habituation directly, but it is more likely that they combine with habituation to modify the subjective experience of the test foods, which is subsequently expressed in the hedonic evaluations upon which we base our current understanding of SSS. Figure 6.1 provides a simple diagram outlining the two possible processes of the proposed model of SSS, combining sensory and cognitive inputs in a serial and in a parallel manner.

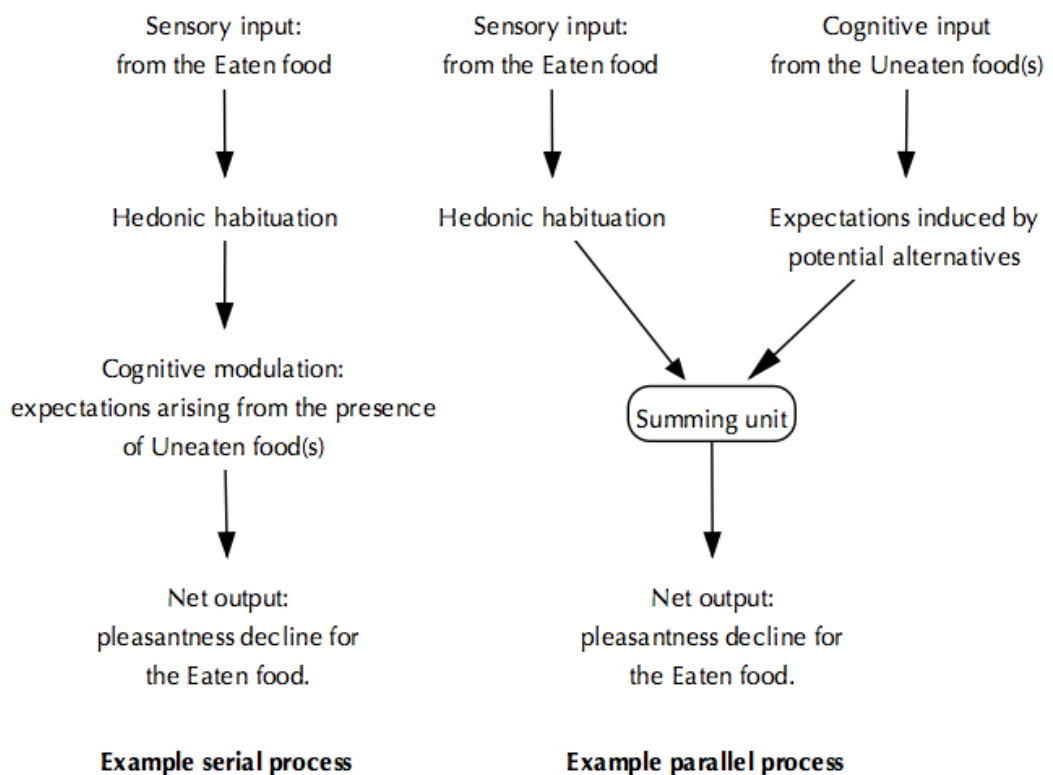


Figure 6.1: Two possibilities for the proposed mechanisms underlying Sensory-Specific Satiety.

The proposed model suggests that SSS is more complex than previously thought, and provides a good explanation for the difficulty researchers face in separating wanting and liking in the SSS testing paradigm (e.g. Berridge, 1996; Mela, 2001; see Section 1.2.1.3: Critique of Sensory-Specific Satiety), particularly if ‘liking’ derives primarily from the hedonic habituation input resulting from the Eaten food, and ‘wanting’ from the expectations induced by the presentation of Uneaten foods. The cognitive element uncovered by the Uneaten food manipulations may represent ‘wanting’; while

pleasantness ratings for the Eaten food in the absence of Uneaten contrasts may represent 'liking'. When measuring SSS we are indeed measuring both motivational and affective responses in parallel (as suggested by Mela, 2001; and evidenced by Havermans, Janssen, et al., 2009), and it is reasonable to assume that the weighting between them may fluctuate as a consequence of the apparent availability and sensory properties of other foods.

6.2.2. The Effects of Repeated Exposure on Sensory-Specific Satiety

To some extent the findings in this thesis support the general literature on dietary learning, in that the phenomena of learned satiety, flavour-flavour learning (FFL) and flavour-consequence learning (FCL) can sometimes be as elusive as sensory-specific satiety (e.g. Yeomans et al., 2005; Yeomans, 2012). Even with meticulous planning, attempting to replicate positive outcomes for these phenomena in the laboratory often results in erratic findings. Dietary learning appears sensitive to a multitude of methodological variables and individual differences, such as: motivational or appetitive state (hunger) at the time of acquisition and the time of expression; dietary restraint; the subjective reward value of the selected reinforcer; the relative difference between low- and high-energy foods; portion size; total energy intake; number and duration of pairings; and baseline ratings for pleasantness and novelty (see Sections 1.3.3: Dietary Learning; and Section 2.3: Participant Selection). Indeed, even when experimental stimuli and procedures are replicated in the same laboratory, there is no guarantee of positive findings for dietary learning (see Section 5.3.4: Exp. 6 Discussion).

Many of these variables were given due consideration in the design of these experiments, with particular attention paid to participant selection and the replication of stimuli that had successfully elicited evidence of dietary learning in this same laboratory. And yet evidence of any form of dietary learning remains absent from the findings. A review of recent published dietary learning studies (Yeomans, 2012) found that 65% of studies reporting liking changes provided evidence for FCL from hedonic measures, and only 25% for FCL from measures of satiation. Yeomans (2012) identifies several factors as likely candidates for the variability in success within these studies, and suggests optimal conditions under which FCL may be observed, and some of those conclusions are pertinent to the research presented here.

Firstly, participant age may be crucial (Brunstrom, 2005), experiments with children producing a greater FCL success rate than those with adults (Yeomans, 2012), and a potential explanation for resistance to dietary learning in adults presents itself in latent inhibition - which may result from exposures to a food stimulus that is not accompanied by a meaningful association. For example, uneventful exposures to a particular flavour may lead a person to learn that there is 'nothing to learn' from that food, that it is not significant – and therefore responses to the stimulus inhibited long-term. Once latent inhibition has occurred for a particular stimulus, one becomes resistant to learning from new associations with which it is paired. Thus, to the extent that the sensory characteristics of the food stimuli are familiar, latent inhibition may prevent adults from acquiring dietary learning from that stimulus.

Secondly, and leading on from the concept of latent inhibition, the CS in dietary learning experiments must be novel, in order to prevent possible interference of latent inhibition. For example, Yeomans (2012) reanalysed data from three previously published from this laboratory (discussed and cited as successful dietary learning studies in Section 1.3.3: Dietary Learning): Mobini et al. (2007); Yeomans et al. (2009); and Yeomans et al. (2008). The reanalysis demonstrated positive correlations between baseline novelty ratings and change in pleasantness to the CS+, indicating an impact of latent inhibition.

Thirdly, energy differences between low- and high-energy stimuli intended to demonstrate FCL must be adequate to allow scope for differentiation; the different versions of the test food must be indistinguishable to the participants; and both versions must be equally palatable. Yeomans (2012) goes further, stating that optimal testing conditions should mean that both versions of the test food should be neither liked nor disliked.

In the experiments presented here, optimal conditions have not been met, in one way or another. To begin with, all participants in the current studies were adults, with at least 19 years prior sensory experience of various food stimuli, and even though the design of the learning experiments (Experiments 5 and 6) intended to ensure the novelty of the CS food, there remains the possibility that failure to produce positive results for dietary learning may be attributed to low novelty ratings for the experimental food. Novelty for the low- and high-energy foods in both experiments could be considered low (discussed further in sections 6.3.3.1: Visual Analogue Scales; and Section 6.3.3.4: Baseline pleasantness and novelty ratings). Finally, there are inadequacies pertaining to the energy

differences, palatability and initial pleasantness ratings for the test foods in these experiments (discussed in Section 5.4: General Discussion of Experiments 5 and 6).

A general publication bias towards positive results may have obscured previous efforts by other researchers to investigate the potential effect of repeated consumption on SSS. Even so, there is currently no evidence in the literature that SSS is modified by repeated consumption. Undeniably there are caveats on the outcome of the studies presented in this thesis, yet evidence that SSS alters as a function of repeated exposure was entirely absent from the findings of these studies too. It remains a possibility that the magnitude of SSS may be subject to changes as a result of repeated exposure, but the lack of evidence here and in the literature would suggest that it is unlikely. The conclusion at this stage must be that SSS is not altered by repeated exposure – accompanied by positive reinforcement or not – with the methodology used in these experiments.

6.3. Shortcomings and Limitations of the Present Work

The findings of the research presented in this thesis are predominantly negative in respect to the original aims. However, these studies have afforded an opportunity to consider a variety of methodological and procedural variables in the way that SSS is experimentally tested. The results have revealed sensory-specific satiety to be somewhat vulnerable to a number of factors that should be considered when drawing conclusions from the work. The remainder of this section outlines the general limitations of participant samples and data analysis, and examines the methodological issues in more depth.

6.3.1. Participant Samples

The participant selection criteria were necessary to ensure maximal likelihood of observing sensory-specific satiety and dietary learning. However, the nature of the recruitment methods and selection criteria resulted in samples that are arguably unrepresentative of the general population. Samples consisted mainly of women in their late teens and early twenties, primarily Caucasian, native English speakers, and educated to university level. Physically all were healthy individuals with BMI in the normal range who rarely, or never smoked tobacco (see Section 2.3: Participant Selection). Consequently, some caution should be exercised if extrapolating these findings to populations that are significantly different from the samples used in this research.

6.3.2. Data Analysis

Data were analysed using methods that mirror those accepted in the literature on sensory-specific satiety and flavour-based learning (see Section 2.1: Methodology and Measurement of SSS in the Literature). Experiment 3 suffered a loss of statistical power when the decision was made to discard data collected by an undergraduate (see Section 4.3.1: Exp. 3 Background), though methodological issues and other confounds doubtless contributed to the negative findings in that experiment. In some instances data failed to meet the assumption of sphericity necessary for mixed, or within-subject analysis of variance (see Sections 5.2.3.3: Exp. 5 Change in Hedonic Ratings Across SSS Test Days; 5.2.3.4: Exp. 5 Change in Initial Pleasantness for the Eaten Food Across SSS Test Days; 5.2.3.6: Exp. 5 Hunger Ratings; 5.3.3.2: Exp. 6 Sensory-Specific Satiety; and 5.3.3.6: Exp. 6 Hunger Ratings), and to mitigate the impact on interpretation of these results, the Greenhouse-Geisser statistics are reported.

6.3.3. Methodological Issues

6.3.3.1. *Visual Analogue Scales*

Visual analogue scales (VAS) were used throughout these experiments, in line with much of the sensory-specific satiety literature that report the use of similar measurement scales (see Section 2.4.1: Laboratory Setup). The unipolar nature of these scales meant that the anchors were labelled 'extremely' and 'not at all', which may have confounded the ratings taken for variables such as pleasantness and novelty. The assumption was that any rating above zero would indicate some degree of the variable being measured. Low participant ratings of novelty and pleasantness however, may have been intended to indicate unpleasantness or familiarity - neither of which were ratings in these experiments. The majority of the studies in the literature use unipolar ratings in the testing of sensory-specific satiety (e.g. Havermans, Janssen, et al., 2009; Smeets & Westerterp-Plantenga, 2006; Vandewater & Vickers, 1996), while some have employed bipolar scales (e.g. Hetherington, et al., 1989 – although in this study unipolar scales were used to rate hunger; Johnson & Vickers, 1992; B. J. Rolls, Hetherington, et al., 1988b). In retrospect bipolar VAS with a clear central point of neutrality may have eliminated ambiguous ratings data in these experiments.

6.3.3.2. *Pre-testing Hunger Ratings*

Many studies in the literature demonstrate that dietary learning is facilitated when participants are trained and tested in a state of hunger (see Section 1.3.3.1: Flavour-Based Learning). When testing for sensory-specific satiety though, evidence for hunger as a factor in consumption-related pleasantness decline is less clear. Whilst hunger may not be a pre-requisite of SSS, general satiety will typically lead to cessation of eating, and a general (rather than sensory-specific) decline in hedonic ratings of foods. Some evidence suggests that liking is linked to hunger. For instance Mobini *et al* (2007) found that a novel flavour paired with sugar received higher pleasantness ratings before lunch than after. Insufficient hunger at the start of SSS testing may therefore set a potential ceiling for pleasantness ratings at baseline, thus reducing the scope for SSS to develop.

The experiments presented in this thesis imposed two different fasting requirements on test days: an overnight fast, followed by a controlled breakfast and a subsequent 3-hour fast (Experiments 1, 2, 5 and 6); or a 2-hour fast after a 'normal lunch' (Experiments 3 and 4). Full details are laid out in Section 2.4.2: Laboratory Breakfasts. Both these patterns are

similar to those employed in the literature, where pre-test fasting has been set at three hours or more (e.g. Hetherington, 1996; Johnson & Vickers, 1992; B. J. Rolls, Hetherington, et al., 1988b; B. J. Rolls & McDermott, 1991; Vandewater & Vickers, 1996); and indeed as little as two hours (e.g. Havermans, Janssen, et al., 2009; Hetherington, et al., 2000). The fasting procedures used in the research for this thesis resulted in moderate hunger ratings throughout, although those from Experiment 3 were lower than others. Therefore three hours appears an optimum duration for fasting prior to SSS testing.

6.3.3.3. Portion size / fixed loads

Fixed portions of the Eaten food, rather than *ad libitum* portions were used in all instances of testing for sensory-specific satiety in these experiments. Controlling for portion size in the consumption phase was intended to provide consistency within and between experiments and participants. A portion size of 50g was selected based on previous research in this laboratory (see Section 2.5: General Procedure). However, in adhering to the 50g serving, the design of some experiments failed to take into account differences in volume between some of the snacks used as Eaten foods, and consequently some results were confounded.

Duration of oral exposure is a critical factor in SSS (Smeets & Westerterp-Plantenga, 2006), and the volume of the food is a better predictor of SSS than the weight (Bell, et al., 2003), therefore fixing the portion size at 50g was sensible for Experiment 1, where the test snacks had similar ratios of weight to volume. However, in Experiments 2 and 3 the differences in density of the snack foods created the very same situation that the use of fixed portions was intended to eliminate: the potential for the foods to be subject to varying degrees of SSS, in this case attributed to differences in oral exposure and effort-to-eat. In Experiment 2, an unwillingness to consume 50g of Apple Chips resulted in the withdrawal of four participants. A similar problem was encountered in Experiment 3, where one participant declined to consume 50g of Rice Cakes. Both these snacks were very lightweight, and a 50g portion presented approximately four or five times the volume of denser snack foods used in testing such as cereal bars, chocolate bars, or fig rolls. The extent of the problem may be greater than is apparent from the number of withdrawn participants. It is likely that other participants found the large portions of these foods unappetising and possibly aversive - if not at the start of the consumption phase, then perhaps by the end - which may have resulted in a negative attitude towards these

foods. Attitude towards the foods is reflected in post-consumption pleasantness ratings, but may also be transferred to the Uneaten foods in the form of a more general loss of appetite. Such a situation would result in lower probability of observing SSS, as differences in pleasantness decline between the Eaten and Uneaten foods could be obscured.

Conversely, findings from Experiments 5 and 6 suggest that 50g fixed portion was too little to elicit SSS. In these instances the Eaten food was blancmange and jelly, respectively. The fixed portion may have limited the extent to which SSS could reasonably develop, as oral exposure and effort to eat were minimal in these foods which required little, if any mastication. Pilot testing should be extended to assess the SSS-potential of the food intended to be consumed in testing. This would enable factors such as effort to eat, volume and oral exposure to contribute to assessing a suitable portion size, whilst retaining the fixed nature of the portion to enable cross- and within-experiment comparison. However, these issues could have been addressed with an 'attention' component in the consumption phase. For example, Havermans, Geschwind, et al. (2009) were successful in inducing SSS for small samples of a liquid stimulus (a flavoured lemonade) that amounted in total to a lower volume than would be necessary to induce SSS under normal conditions. This was achieved by giving participants instructions that required them to pay particular attention to the beverage upon each mouthful, and thus the oral exposure to the stimulus was extended far beyond that which may have been achieved in the current experiments. Therefore, smaller portions of food and beverages that may require less oral processing than solid foods, were attended to in the same way as stimuli that required more effort to eat. The methods used by Havermans, Geschwind, et al. (2009) were published after the data collection phases for these studies, but nevertheless provides useful guidance for future SSS testing when using stimuli for which it is easy to consume quickly.

6.3.3.4. *Baseline pleasantness and novelty ratings*

Baseline pleasantness and novelty ratings of the consumed (Eaten) food appear to play a significant role in the development of SSS, and together accounted for more variation in pleasantness decline than did manipulation of the Eaten food (see Section 4.4.4: Exp. 4 Discussion). The impact of low pleasantness ratings for some foods were minimised by counterbalancing snacks as the Eaten food in Experiments 1, 2 and 3. The Eaten food was not counterbalanced in Experiment 4, and the Ryvia (Eaten food, savoury) was rated low

for pleasantness, which presented a confound in interpreting the results. In many experiments the baseline ratings for pleasantness and novelty bear little resemblance to those collected during the pilot testing used to select the test foods. A simple explanation is that smaller participant samples were used in pilot testing, a tactic that may have limited the extent to which rated pleasantness and novelty will generalise to a larger sample of participants. Another concern is that often during pilot testing, participants were asked to rate up to twelve foods in a single sitting. General satiety and habituation to similar sensory properties (such as sweet and savoury tastes) could skew ratings for the snacks tasted last. Although the order of tasting snacks was randomised for each participant in pilot testing – in order to prevent just such an issue – with a small sample size, the results would still be unreliable to a certain extent.

6.4. Implications of the Present Work for Future Research

The research proffered in this thesis has implications for future research that emerge from the main findings and more importantly, from the limitations and pitfalls met during the research process. What follows is a series of suggestions arising from this research that may guide future research into the nature of sensory-specific satiety.

A number of the issues encountered could be obviated during pilot testing, prior to experimentation. For these experiments, snack foods were piloted only to assess whether they were novel and moderately pleasant, and consequently there was a failure to anticipate problems with particular foods. Firstly, ratings of pleasantness and novelty from pilot tests were not replicated on experimental test days, often resulting in lower ratings and presenting potential ceiling and floor effects (and one food, Ryvita, that may have been disliked) in the actual experiments. Two factors may improve the correlation between pilot and experimental ratings: reducing the number of foods sampled during piloting (to avoid sensory fatigue), and increasing the sample size of participants in the pilot phase to increase statistical power, and to enhance the likelihood of pilot data that is representative of data likely to be generated from a larger sample at testing. Secondly, the findings suggest that each Eaten food stimulus has its own potential to induce SSS, and this will vary according to the weight-to-volume ratio, effort required to consume the food, and duration of oral exposure experienced during consumption. Piloting for foods intended for use as the Eaten food should therefore be extended to include the SSS paradigm, so that fixed portions may be adjusted to induce the optimum SSS for each specific food. In the experiments presented here, fixing the Eaten food portion at 50g worked only for some foods (Chocolate bar and Cereal bar). However, light snacks had a tendency to result in a portion that was simply too large to comfortably consume (Apple Chips and Rice Cakes); and more dense foods that required less effort to eat resulted in portions simply too small for sufficient oral exposure to enable significant post-consumption pleasantness decline (Blancmange and Jelly).

Consideration should also be given to the use of visual analogue scales (VAS). Unipolar scales were employed throughout these experiments, but presented an opportunity for ambiguous interpretation. Whilst polarity anchors for the ratings were clearly marked as 'Not at all' and 'Extremely' for each hedonic and appetite measure, in the context of pleasantness 'Not at all' may have been construed as a *dislike*. This is not the intended use of the scale, but nevertheless a possible user interpretation. Some variables lend

themselves well to bipolar scales, such as Novel-Familiar and Pleasant-Unpleasant. Combined with better pilot testing for these attributes, bipolar scales may generate more reliable results on which to base food selection for experiments.

Attention should be paid to the motivational state of participants when testing commences. A state of hunger is not necessary, but a state of satiety is undesirable, and may confound ratings of pleasantness during testing. Ratings of hunger from the experiments that required a pre-testing fast of only two hours (after instructions to have a 'normal lunch') were slightly below the mid-point on the scale. Where a 3-hour fast followed an overnight fast and controlled breakfast, hunger ratings were not so low as to cause concern, yet ratings were clearly more uniform across the conditions. Consideration should be given to the way that fasting is implemented - the controlled breakfast and three-hour fast worked well and allowed for more control over intake prior to testing. The 2-hour fast may have been sufficient to generate the moderate hunger ratings desired, but may have generated more reliable hunger levels if the lunch had been controlled for and consumed in the laboratory.

Finally, the work to establish the role of Uneaten foods in the development of SSS is unfinished. Evidence for a greater magnitude of pleasantness decline when the Eaten food is accompanied by two Uneaten foods was not replicated, but the subsequent attempts to confirm these findings fell short of creating a true test of the phenomenon. In view of this unanswered question, and as the evidence presented here currently stands, one sweet and one savoury Uneaten food may tender the optimum SSS for a sweet Eaten snack food.

6.5. Conclusions

The findings from these experiments are inconclusive with regard to the original aims, largely due to methodological issues arising from the design and implementation of the experiments presented. The issues may have contributed to undermining the expression of SSS and dietary learning in the laboratory, but cannot be cited as conclusive evidence that neither phenomenon exists. It is still unclear whether dietary learning, or multiple non-reinforced exposures to a novel food have a modulating effect on SSS. The experiments in this thesis suggest that Uneaten contrasts have a role to play in the development of SSS, but the nature of that role may be cognitive, and is not clarified by the results presented here. Therefore, the questions raised in the original objectives are yet to be answered, and further research, perhaps drawing from the lessons learned from these studies, should address once more the question of whether the magnitude of SSS is subject to modulation as a consequence of multiple exposures to novel foods – especially once the nature of overlap between habituation and SSS is understood more fully.

This document does succeed in presenting an exploration of the conditions under which SSS may or may not be expressed, highlighting both good practice and potential pitfalls in complex experimental design, where multiple phenomena are under investigation (SSS and dietary learning). In conclusion, this thesis is viewed best as a methodological and procedural manual for laboratory testing of sensory-specific satiety in humans.

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Appendices

Appendix A: Example recruitment email

Greetings ladies and gentlemen,

Would you like to participate in my snack and drink study? I can give you 4 hours credits + £10, or less credits and more money, on a sliding scale. If you don't need any more credits, I can give you £30 for doing my study.

It involves coming to the lab on any six weekdays (they can be consecutive): in the morning for a cereal breakfast (takes 15 mins), then coming back 3 hours later to taste some snacks or rate some drinks, and report on your mood (takes about 30 mins).

Participation Criteria: please read carefully:

- You must be between 18 and 55 years old.
- You must be trustworthy and reliable.
- You should not take part if you:
- have taken part in one of my previous experiments (I can check this for you).
- have taken part, or are currently taking part in an experiment in our lab involving sorbet, soup, porridge or drinks.
- are diabetic.
- smoke more than 5 cigarettes per week.
- are currently taking prescribed medication (excluding oral contraceptive pills).
- have previously been diagnosed with an eating disorder.
- are currently dieting.
- are vegetarian (products may contain gelatine).
- you have an allergy or aversion to any of the foods or food ingredients listed here: Sugars, artificial sweeteners, glycerol, plant oils, soya derivatives, food flavourings, food colourings, cereal-based products (e.g. wheat, oats, rice, barley), dairy products (e.g. milk, cheese, butter), fruit and fruit juices, nuts, chocolate, yoghurt, gelatine.

If you meet the above criteria and would like to take part, please complete our short eating behaviour questionnaire online here

(www.sussex.ac.uk/units/socpsy/webq/recruit/index.html) and email me - this allows me to establish your suitability for this experiment. If you have already completed the questionnaire this academic year, you don't need to do it again, just email me. You may then be invited to a short (10 minute) screening session. If you attend a screening session and are not selected to take part in this experiment, you will be given £2 (or 15 minutes course credit if you prefer) for your time.

If you are selected to take part, you can look forward to 6 breakfasts, 4 drinks and 2 snacking sessions. Oh, and of course the £30 cash, or cash and course credits.

I look forward to hearing from you,
Sarah

Appendix B: Laboratory Questionnaire

Name: _____		Status: UG / PG / Staff / Other-please write below!
GIVEN NAME	FAMILY NAME/S	
Contact address: _____		School and/or pigeonhole: _____
Telephone/s: Land: _____ Mobile: _____		Gender: Female / Male
Email at Sussex: _____		Other email: _____
Which is the best way for us to contact you?		Date of Birth: ____/____/____ dd mm yyyy
Are you available during any vacations? Yes/No Vacation contact: _____		
In what year do you expect to leave Sussex (if known)? _____		Today's Date: ____/____/____ dd mm yyyy

The following questions allow us to identify your suitability to take part in our research. Different studies suit different people, so please answer the questions as accurately as possible. Your answers are confidential, and will be kept on file for future studies, until you leave Sussex or ask us to remove you from our database.

Please answer these questions by ***circling*** the answer (True) or (False) that best describes your behaviour:

- | | | |
|----|---|------------|
| 1 | When I see a sizzling steak or see a juicy piece of meat, I find it difficult to keep from eating, even if I have just finished a meal | True/False |
| 2 | I usually eat too much at social occasions, like parties and picnics | True/False |
| 3 | I am usually so hungry that I eat more than three times a day | True/False |
| 4 | When I have eaten my quota of calories, I am usually good about not eating any more | True/False |
| 5 | Dieting is so hard for me because I just get too hungry | True/False |
| 6 | I deliberately take small helpings as a means of weight control | True/False |
| 7 | Sometimes things just taste so good that I keep on eating even when I am no longer hungry | True/False |
| 8 | Since I am often hungry, I sometimes wish that while I am eating, an expert would tell me that I have had enough or that I can have something more to eat | True/False |
| 9 | When I feel anxious, I find myself eating | True/False |
| 10 | Life is too short to worry about dieting | True/False |
| 11 | Since my weight goes up and down, I have gone on reducing diets more than once | True/False |
| 12 | I often feel so hungry that I just have to eat something | True/False |
| 13 | When I am with someone who is overeating, I usually overeat too | True/False |
| 14 | I have a pretty good idea of the number of calories in common foods | True/False |
| 15 | Sometimes when I start eating, I just can't seem to stop | True/False |
| 16 | It is difficult for me to leave something on my plate | True/False |
| 17 | At certain times of the day, I get hungry because I have got used to eating then | True/False |
| 18 | While on a diet, if I eat food that is not allowed I conscientiously eat less for a period of time to make up for it | True/False |

CC ☐ FC ☐ PL ☐ CP ☐ ST ☐ CH ☐ DNS ☐ Other ☐

19	Being with someone who is eating often makes me hungry enough to eat also	True/False
20	When I feel blue, I often overeat	True/False
21	I enjoy eating too much to spoil it by counting calories or watching my weight	True/False
22	When I see a real delicacy, I often get so hungry that I have to eat right away	True/False
23	I often stop eating when I am not really full as a conscious means of limiting the amount that I eat	True/False
24	I get so hungry that my stomach often seems like a bottomless pit	True/False
25	My weight has hardly changed at all in the last ten years	True/False
26	I am always hungry so it is hard for me to stop eating before I finish the food on my plate	True/False
27	When I feel lonely I console myself by eating	True/False
28	I consciously hold back at meals in order not to gain weight	True/False
29	I sometimes get very hungry late in the evening or at night	True/False
30	I eat anything I want, any time I want	True/False
31	Without even thinking about it, I take a long time to eat	True/False
32	I count calories as a conscious means of controlling my weight	True/False
33	I do not eat some foods because they make me fat	True/False
34	I am always hungry enough to eat at any time	True/False
35	I pay a great deal of attention to changes in my figure	True/False
36	While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high calorie foods	True/False
37	If I eat a little bit more one day, I make up for it the next day	True/False
38	I eat diet foods, even if they do not taste very good	True/False
39	A diet would be too boring a way for me to lose weight	True/False
40	I pay attention to my figure, but I still enjoy a variety of foods	True/False
41	I would rather skip a meal than stop eating in the middle of one	True/False
42	I alternate between times when I diet strictly and times when I don't pay attention to what and how much I eat	True/False
43	I prefer light foods that are not fattening	True/False
44	Sometimes I skip meals to avoid gaining weight	True/False
45	I try to stick to a plan when I lose weight	True/False
46	If I eat a little bit more during one meal, I make up for it at the next meal	True/False
47	Without a diet plan I wouldn't know how to control my weight	True/False
48	Quick success is more important for me during a diet	True/False

Again, please answer the questions by putting a *circle* around the answer that best describes your behaviour:

49	How often are you dieting in a conscious effort to control your weight?	Rarely Sometimes Usually Always
50	Would a weight fluctuation of 5lbs affect the way you live your life?	Not at all Slightly Moderately Very much
51	How often do you feel hungry?	Only at mealtimes Sometimes between meals Often between meals Almost always
52	Do your feelings of guilt about overeating help you to control your food intake?	Never Rarely Sometimes Always
53	How difficult would it be for you to stop eating halfway through dinner and not eat for the next four hours?	Easy Slightly difficult Moderately difficult Very difficult
54	How conscious are you of what you eat?	Not at all Slightly Moderately Extremely
55	How frequently do you avoid stocking up on tempting food?	Almost never Seldom Usually Almost always
56	How likely are you to shop for low calorie foods?	Unlikely Slightly unlikely Moderately likely Very likely
57	Do you eat sensibly in front of others and splurge alone?	Never Rarely Often Always
58	How likely are you to consciously eat slowly in order to cut down on how much you eat?	Unlikely Slightly unlikely Moderately likely Very likely
59	How frequently do you skip dessert because you are no longer hungry?	Almost never Seldom At least once a week Almost every day
60	How likely are you to consciously eat less than you want	Unlikely Slightly likely Moderately likely Very likely
61	Do you go on eating binges though you are not hungry?	Never Rarely Sometimes At least once a week
62	Do you deliberately restrict your intake during meals even though you would like to eat more?	Rarely Sometimes Usually Always

- 63 On a scale of 0 to 5, where 0 means no restraint in eating (eating whatever you want, whenever you want it) and 5 means total restraint (consciously limiting food intake and never 'giving in'), what number would you give yourself? (Please circle one number only.)

- 0) Eat whatever you want, whenever you want it
- 1) Usually whatever you want, whenever you want it
- 2) Often whatever you want, whenever you want it
- 3) Often limit food intake, but often 'give in'
- 4) Usually limit food intake, and rarely 'give in'
- 5) Constantly limit food intake, never 'give in'

- 64 To what extent does this statement describe your eating behaviour? "I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat whatever I want, promising myself to start dieting again tomorrow" (Please circle one number only.)

0 Not like me. 1 A little like me. 2 A pretty good description of me. 3 Describes me perfectly.

PTO

Drinking Habits and Preferences

65 On average, how many cups or mugs of the following coffees do you drink in a typical day?

Instant coffee [_____] Decaff instant [_____] Filter coffee [_____] Decaff filter [_____]

Other coffee (please specify number & type here): [_____] _____

66 On average, how many cups or mugs of the following teas do you drink in a typical day?

Regular tea [_____] Decaff tea [_____] Herbal tea [_____] Fruit tea [_____]

Other tea (please specify number & type here): [_____] _____

67 On average, how many cans of the following soft drinks do you drink in a typical day?

Cola [_____] Decaff cola [_____] Fruit drinks [_____] Red Bull [_____] Others [_____]

68 On average, how many glasses of fruit juice do you drink in a typical day? [_____]

69 On average, how many glasses of water do you drink in a typical day? [_____]

70 How many units of alcohol do you usually drink in a week? (Please tick one)
(1 unit = 1/2 pint of beer, 1 glass of wine; 1 single measure of spirits, 1/3 pint of cider)

None [_____] Less than 10 [_____] 10 – 20 [_____] 20 - 30 [_____] 30+ [_____]

71 What do you drink? (Please tick all that apply)

Alco-pops [_____] Lager [_____] Ale [_____]

Cider [_____] Wine [_____] Spirits [_____]

72 What sort of drink do you normally have when you first get up in the morning?
(Please describe accurately below - e.g. Mug of instant coffee with milk and one sugar)

73 How did you hear about our research?

Poster in LifeSci [_____] Poster elsewhere [_____] SEO [_____] Friend [_____] Other-*please write below*

74 Please put a mark on the line to show how hungry you are right now, paying attention to the descriptions at the end of the line.

Not at all hungry _____ Extremely hungry

PTO

Food Likes and Dislikes

How pleasant would you rate each of the following foods?

For breakfast:

75	Crunchy Nut Cornflakes with milk	Very pleasant	Moderately pleasant	Very unpleasant
76	Toast with butter and jam	Very pleasant	Moderately pleasant	Very unpleasant
77	Bacon and fried eggs	Very pleasant	Moderately pleasant	Very unpleasant
78	Fruit yoghurt	Very pleasant	Moderately pleasant	Very unpleasant

For lunch or dinner:

79	Pasta in a cheese sauce	Very pleasant	Moderately pleasant	Very unpleasant
80	Vegetables in hot chilli sauce	Very pleasant	Moderately pleasant	Very unpleasant
81	Mild chicken curry and rice	Very pleasant	Moderately pleasant	Very unpleasant
82	Pasta in a tomato & onion sauce	Very pleasant	Moderately pleasant	Very unpleasant

83 Which of the following best describes your eating habits? (Please tick one)

- ☐ Eat all meat
- ☐ Eat only white meat and fish
- ☐ Eat fish only
- ☐ Strict vegetarian
- ☐ No animal products (vegan)

84 Do you smoke? YES/NO

If yes, how many a day? 1-5 6-10 10-20 20+ (Please circle one answer)

85 Do you speak English as a first or 'native' language? YES/NO

Finally, do you have any:

86 Food allergies? YES/NO

If YES, please give *brief* details here:

87 Food aversions? YES/NO

If YES, please give *brief* details here:

THANK YOU very much for your time. Please fold the form carefully so that the return address is clearly visible on the outside, and return it to us a.s.a.p. If you are on campus, you can do this using your School's internal mail. If you are returning the form from off-campus, then you should use an envelope and a postage stamp. Once we have entered your details onto our database, we shall contact you as soon as a suitable study is running.

IMPORTANT: Please ensure that you have answered ALL of the questions, especially those at the top of the first page. If you do not make your name and other contact details clear, then we may not be able to contact you when we need to do so.

Appendix C: Information for Participants in Experiment 1

Information for Participants

The Purpose of the Experiment

This experiment will examine the relationship between mood and food.

What you will be required to do

You will come to the Ingestive Behaviour Unit on two separate days for testing. There will be two weeks between the two testing days.

On both test days you will attend the Ingestive Behaviour Unit between 08:00 and 09:30 having drunk only water, and not consumed any food from 23:00 the night before. You will be given a breakfast of Kellogg's Crunchy Nut Cornflakes with semi-skimmed milk and a glass of orange juice.

After you have eaten breakfast, you will be free to leave the lab, but you will refrain from eating for two hours. You will return to the Unit two hours after breakfast for testing.

You will return to the lab exactly two weeks later to repeat the whole procedure. The study will take a maximum total of two hours of your time, and you will be paid £10 on completion, or receive the relevant amount of course credits, whichever you prefer.

[Instructions to participants in the experimental conditions that were to receive snacks for home consumption contained one of the following three paragraphs:]

[snack: chocolate bars]: During the two weeks between testing days you will be required to consume one portion of chocolate bar snack per day. These will be given to you by the investigator, along with a form to complete each time you eat a portion of the snack. Starting tomorrow, please ensure you eat one whole portion per day for the next thirteen days.

[snack: cereal bars]: During the two weeks between testing days you will be required to consume one portion of cereal bar snack per day. These will be given to you by the investigator, along with a form to complete each time you eat a portion of the snack. Starting tomorrow, please ensure you eat one whole portion per day for the next thirteen days.

[snack: salty potato snacks]: During the two weeks between testing days you will be required to consume one portion of savoury potato snacks per day. These will be given to you by the investigator, along with a form to complete each time you eat a portion of the snack. Starting tomorrow, please ensure you eat one whole portion per day for the next thirteen days.

The tests

You will complete subjective ratings on several food- and mood-related measures, and sample and evaluate two foods on several taste measures.

Precautions

- You should not take part if you:
- are diabetic
- smoke more than 5 cigarettes per day
- are currently taking prescribed medication (excluding oral contraceptive pills)
- have a prior history of, or are currently suffering from a clinical eating disorder
- are currently dieting
- you have an allergy or aversion to any of the foods or food ingredients listed below:
Sugars, glycerol, plant oils, soya derivatives, food flavourings, food colourings, cereal-based products (e.g. wheat, oats, rice, barley), dairy products, fruit and fruit juices, nuts, chocolate, yoghurt.

If you have any queries or concerns, please contact me:

Sarah Robins, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 873451, email S.L.Robins@sussex.ac.uk

Or the Principle Investigator:

Dr Martin Yeomans, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 678617, email martin@sussex.ac.uk

You have the right to withdraw from this study at any time.

Appendix D: Information for Participants in Experiment 2

Information for Participants

The Purpose of the Experiment

This experiment will evaluate the effect of food on mood.

What you will be required to do

You will come to the Ingestive Behaviour Unit between 08:00 and 09:30 having drunk only water, and not consumed any food from 23:00 the night before. You will be given a breakfast of Kellogg's Crunchy Nut Cornflakes with semi-skimmed milk and a glass of orange juice.

After you have eaten breakfast, you will be free to leave the lab, but you will refrain from eating for two hours. You will return to the Unit two hours after breakfast for testing, when you will complete ratings on several food- and mood-related measures, and sample and rate snacks.

The study will take a maximum total time of one hour, and you will be paid £5 on completion, or receive one hour of course credits, whichever you prefer.

Precautions: please read carefully

You should **not** take part if you:

- are diabetic
- smoke more than 5 cigarettes per day
- are currently taking prescribed medication (excluding oral contraceptive pills)
- have a prior history of, or are currently suffering from a clinical eating disorder
- are currently dieting
- are vegetarian
- you have an allergy or aversion to any of the foods or food ingredients listed below:

Sugars, glycerol, plant oils, soya derivatives, food flavourings, food colourings, cereal-based products (e.g. wheat, oats, rice, barley), dairy products (e.g. milk, cheese, butter), fruit and fruit juices, nuts, chocolate, yoghurt.

If you have any queries or concerns, please contact me:

Sarah Robins, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 873451, email S.L.Robins@sussex.ac.uk

Or the Principle Investigator:

Dr Martin Yeomans, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 678617, email martin@sussex.ac.uk

You have the right to withdraw from this study at any time.

Appendix E: Information for Participants in Experiment 3

Information for Participants

The Purpose of the Experiment

This experiment will evaluate the effect of food on mood.

What you will be required to do

You will come to the Ingestive Behaviour Unit at an agreed time between 14.00 and 17.00 having eaten a normal lunch and then drunk only water for a minimum of 2 hours after lunch before the testing starts. In the lab you will complete ratings on several food- and mood-related measures, and sample and rate snacks.

The study will take a maximum total time of 30 minutes, and you will be paid £3 on completion.

Precautions: please read carefully

You should **not** take part if you:

- are diabetic
- smoke more than 5 cigarettes per day
- are currently taking prescribed medication (excluding oral contraceptive pills)
- have a prior history of, or are currently suffering from a clinical eating disorder
- are currently dieting
- are vegetarian
- you have an allergy or aversion to any of the foods or food ingredients listed below:
Nuts, Wheat or other cereals, Sugars, Artificial sweeteners, Dairy products, Flavourings.

If you have any queries or concerns, please contact me:

Sarah Robins, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 873451, email S.L.Robins@sussex.ac.uk

Or the Principle Investigator:

Dr Martin Yeomans, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 678617, email martin@sussex.ac.uk

You have the right to withdraw from this study at any time.

Appendix F: Information for Participants in Experiment 4

Information for Participants

The Purpose of the Experiment

This experiment will evaluate the effect of food on mood.

What you will be required to do

You will come to the Ingestive Behaviour Unit at your appointment time (between 14.00 and 16.30), which will be at least two hours since eating your normal lunch. You will have eaten nothing since finishing your lunch, and will have drunk only water. In the lab you will complete ratings on several food- and mood-related measures, and sample some snacks, which you will be asked to rate.

The study will take a maximum total time of 30 minutes. On completion, you will either be paid £3, or receive 30 minutes course credits, whichever you prefer.

Precautions: please read carefully

In order to take part, you **must be**:

- Between 18 and 55 years of age on the day you participate
- Female

You should **not** take part if you:

- are diabetic
- smoke more than 5 cigarettes per week
- are currently taking prescribed medication (excluding oral contraceptive pills)
- have a prior history of, or are currently suffering from a clinical eating disorder
- are currently dieting
- are vegetarian
- you have an allergy or aversion to any of the foods or food ingredients listed here: Nuts, Wheat or other cereals (e.g. oats, rice, barley), Glycerol, Plant oils, Soya derivatives, Sugars, Artificial Sweeteners, Dairy products, Fruit, Chocolate, Yoghurt, Food flavourings, Food colourings.

If you have any queries, concerns, or further questions about this study, please contact me:

Sarah Robins-Hobden, Department of Psychology, University of Sussex, BN1 9QH
Email : S.L.Robins@sussex.ac.uk

Or the Principle Investigator:

Dr Martin Yeomans, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 678617, email martin@sussex.ac.uk

You have the right to withdraw from this study at any time.

Appendix G: Information for Participants in Experiment 5

Information for Participants

The Purpose of the Experiment

This experiment will evaluate the relationship between snack foods and measures of mood.

What you will be required to do

You will complete an eating behaviour questionnaire so we can establish your suitability for this particular experiment.

You will come to the Ingestive Behaviour Unit on eleven non-consecutive days for testing. On each test day you will arrive between 08:00 and 09:30, having drunk only water, and not consumed any food from 23:00 the night before. You will be given a breakfast of cereal with semi-skimmed milk and a glass of orange juice. You may choose between Kellogg's Crunchy Nut Cornflakes or Kellogg's Special K, but you will be required to stick to your selection for the duration of the experiment.

After you have eaten breakfast, you will be free to leave the lab, but you will refrain from eating for three hours. You will return to the Unit three hours after breakfast for testing as follows:

- On three of the test days you will complete ratings on several food- and mood-related measures, and sample and rate snack foods.
- On eight of the test days you will complete ratings on several food- and mood-related measures, and consume a portion of one snack. You will be required to refrain from eating or drinking anything except water for one hour afterwards. After the hour is up, you will complete a final ratings sheet.

Saliva samples will be taken on a random basis to ensure compliance with the restriction on eating and drinking before and during test days.

The study will take a total time of ten hours maximum over the eleven test days, and will most likely take less. You will be paid £50 on completion of the final test day, which may be substituted in part for course credits if you so desire. An experimental "timeline" is included as part of this document.

Participation Criteria: please read carefully

You must be between 18 and 55 years old.

You should **not** take part if you:

- are diabetic
- smoke more than 5 cigarettes per week
- are currently taking prescribed medication (excluding oral contraceptive pills)
- have previously been diagnosed with an eating disorder
- are currently dieting

- are vegetarian
- you have an allergy or aversion to any of the foods or food ingredients listed here: Sugars, glycerol, plant oils, soya derivatives, food flavourings, food colourings, cereal-based products (e.g. wheat, oats, rice, barley), dairy products (e.g. milk, cheese, butter), fruit and fruit juices, nuts, chocolate, yoghurt, gelatine.

If you have any queries or concerns, please contact me:

Sarah Robins, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 873451, email S.L.Robins@sussex.ac.uk

Or the Principle Investigator:

Dr Martin Yeomans, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 678617, email martin@sussex.ac.uk

You have the right to withdraw from this study at any time.

Appendix H: Information for Participants in Experiment 6

Information for Participants

The Purpose of this Experiment is to evaluate the relationship between snack foods and measures of mood.

What you will be required to do

You will complete an online eating behaviour questionnaire, and attend a screening session to establish your suitability for this experiment. The screening will take a few minutes, during which you will taste and rate several solutions. If you attend a screening and are not selected to take part in this experiment, you will be given £2 (or 15 minutes course credit if you prefer).

If selected to take part, you will come to the Ingestive Behaviour Unit on six days for testing. On the morning of each test day you will arrive at your appointment time, having consumed no food and drunk only water from 11pm the night before. You will eat a breakfast of cereal with semi-skimmed milk, and a glass of orange juice. You may choose either Kellogg's Crunchy Nut Cornflakes or Kellogg's Special K as your cereal for the whole experiment.

After finishing your breakfast, you will be free to leave the lab, and will return three hours later for testing. During this time you will refrain from eating or drinking anything except water. The testing appointments are as follows:

- On first and last test days you will complete ratings on several food- and mood-related measures, and sample and rate snack foods.
- On the other four test days you will complete ratings on several food- and mood-related measures, and consume a drink. You will then be free to leave the lab and the experimenter will give you a ratings sheet to take with you. You will be required to refrain from eating or drinking anything except water for one hour, and then complete the ratings sheet and bring it back at your next appointment.

During the time period of your participation in this experiment, you may not participate in any other experiments in the food lab.

Saliva samples may be taken on a random basis to ensure compliance with the restrictions on eating and drinking before and during test days.

The study will take a total maximum time of six hours and you will be paid £30 on completion, which may be substituted in part for course credits if you prefer.

Participation Criteria: please read carefully

You must be between 18 and 55 years old.

You should **not** take part if you:

- have taken part in one of my previous experiments (I can check this for you).
- have taken part in an experiment in our lab involving sorbet, soup, porridge or drinks.

- are diabetic.
- smoke more than 5 cigarettes per week.
- are currently taking prescribed medication (excluding oral contraceptive pills).
- have previously been diagnosed with an eating disorder.
- are currently dieting.
- are vegetarian (products may contain gelatine).
- you have an allergy or aversion to any of the foods or food ingredients listed here:
Sugars, artificial sweeteners, glycerol, plant oils, soya derivatives, food flavourings, food colourings, cereal-based products (e.g. wheat, oats, rice, barley), dairy products (e.g. milk, cheese, butter), fruit and fruit juices, nuts, chocolate, yoghurt, gelatine.

If you have any queries or concerns, please contact me:

Sarah Robins-Hobden, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 873451, email S.L.Robins@sussex.ac.uk

Or the Principle Investigator:

Dr Martin Yeomans, Department of Psychology, University of Sussex, BN1 9QH
Tel: 01273 678617, email martin@sussex.ac.uk

You have the right to withdraw from this study at any time.

Appendix I: Example Participant Consent Form

I have read and had explained to me the information sheet (of which I retain a copy), and I confirm I meet the criteria for participation.

The nature and purpose of the psychological testing has been explained to me.

I am aware that I have the right to withdraw from the experiment at any time.

I fully understand the purpose of the study and freely give my consent to participate.

Name:

Date of Birth:

_____/_____/_____

Sussex email address:

Other email address:

Signed:

Date:

_____/_____/_____

For Experimenter Use Only	
W	
H	
P code(s)	C code

Appendix J: Participant Debrief Form for Experiment 1

Experiment 1 Debrief

P _____

What do you think the study was about?

Any problems or concerns about the study? Feedback on the design?

Appendix K: VAS for Experiment 5 Pilot

Name

Sex

Snack

Place a vertical line through the scale in the position that best describes your assessment of the snack.

Please taste the snack and mark your assessment of it on the following scales:

Sweetness:

Not at all sweet

Extremely sweet

Pleasantness:

Not at all pleasant

Extremely pleasant

Bitterness:

Not at all bitter

Extremely bitter

Creaminess:

Not at all creamy

Extremely creamy

Novelty:

Not at all novel

Extremely novel

Name

Sex

Snack

Place a vertical line through the scale in the position that best describes your assessment of the snack.

Appendix L: VAS for Exposure Sessions in Experiment 5

P No.

Session

Time (1)

Using these scales:

Place a vertical line through the scale in the position that best describes how you feel **right now**, as shown in this example:

EXAMPLE

Happiness:

Not at all happy

Extremely happy

- Please answer how you feel **right now**:

Alert:

Not at all alert

Extremely alert

Hungriness:

Not at all hungry

Extremely hungry

Relaxed:

Not at all
relaxed

Extremely relaxed

Thirstiness:

Not at all thirsty

Extremely thirsty

Tense:

Not at all tense

Extremely tense

Fullness:

Not at all full

Extremely full

Lethargic:

Not at all
lethargic

Extremely lethargic

- Now please turn the page.

P No. Session Time (2)

Please **taste** the snack and mark your assessment of it on the following scales:

Sweetness:
Not at all sweet |-----| Extremely sweet

Sourness:
Not at all sour |-----| Extremely sour

Pleasantness:
Not at all pleasant |-----| Extremely pleasant

Bitterness:
Not at all bitter |-----| Extremely bitter

Novelty:
Not at all novel |-----| Extremely novel

And finally, how strong is your desire to eat more of this snack?

Not at all strong
desire |-----| Extremely strong
desire

- Now please eat **all** of the snack.
- When you have finished, please turn the page.

P No. Session Time (3):

- Please answer how you feel **right now**:

Alert:
Not at all alert |-----| Extremely alert

Hungriness:
Not at all hungry |-----| Extremely hungry

Relaxed:
Not at all relaxed |-----| Extremely relaxed

Thirstiness:
Not at all thirsty |-----| Extremely thirsty

Tense:
Not at all tense |-----| Extremely tense

Fullness:
Not at all full |-----| Extremely full

Lethargic:
Not at all lethargic |-----| Extremely lethargic

- Now please call the experimenter.

P No. Session Time (4):

- Please do not eat or drink anything except water for **1-hour** after you have left the laboratory.
- Please complete this sheet once the **1 hour** period is up.
- Today, that means completing this sheet at _____
- Please answer how you feel **right now**:

Alert:

Not at all alert |-----| Extremely alert

Hungriness:

Not at all hungry |-----| Extremely hungry

Relaxed:

Not at all relaxed |-----| Extremely relaxed

Thirstiness:

Not at all thirsty |-----| Extremely thirsty

Tense:

Not at all tense |-----| Extremely tense

Fullness:

Not at all full |-----| Extremely full

Lethargic:

Not at all lethargic |-----| Extremely lethargic

- Please bring this sheet with you when you next visit the lab.

Appendix M: Participant Debrief Form for Experiment 5

Some final questions...

The Purpose of the Experiment

In your own words, please write one or two sentences on what you think this experiment was about:

When you have finished, please turn over the page.

Q1 Do you think there was any difference between the pink snacks you ate on “computer” test days, and “pen & paper” test days?

(please tick one)

Yes ☐

No ☐

Q2 How certain are you?

Not at all
certain

Extremely
certain

Q3 If you answered “Yes” to **Q1**, what do you think was different?

Appendix N: Sweet-liker Screening VAS for Experiment 6

Name

Date

Using these scales: Place a **vertical line** through the scale in the position that best describes how you rate the solution on each measure, as shown in this example:

EXAMPLE

Fruity:

Not at all fruity |-----| Extremely fruity

/

Please taste solution **A** and rate it on the following scales:

Sweetness:

Not at all sweet |-----| Extremely sweet

Sourness:

Not at all sour |-----| Extremely sour

Pleasantness:

Not at all pleasant |-----| Extremely pleasant

Bitterness:

Not at all bitter |-----| Extremely bitter

Please taste solution **B** and rate it on the following scales:

Sweetness:

Not at all sweet |-----| Extremely sweet

Sourness:

Not at all sour |-----| Extremely sour

Pleasantness:

Not at all pleasant |-----| Extremely pleasant

Bitterness:

Not at all bitter |-----| Extremely bitter

Now please turn the page.

Please taste solution **C** and rate it on the following scales:

Sweetness:

Not at all sweet

Extremely sweet

Sourness:

Not at all sour

Extremely sour

Pleasantness:

Not at all pleasant

Extremely pleasant

Bitterness:

Not at all bitter

Extremely bitter

Please taste solution **D** and rate it on the following scales:

Sweetness:

Not at all sweet

Extremely sweet

Sourness:

Not at all sour

Extremely sour

Pleasantness:

Not at all pleasant

Extremely pleasant

Bitterness:

Not at all bitter

Extremely bitter

The screening session is now complete – please call the experimenter.

Appendix O: VAS for Experiment 6 Pilot

Participant

Please taste the drink

How novel is the flavour of the drink?

Not at all novel

Extremely novel

How sweet is the drink?

Not at all sweet

Extremely sweet

How bitter is the drink?

Not at all bitter

Extremely bitter

How pleasant is the drink?

Not at all pleasant

Extremely pleasant

Now Please taste the jelly - please take your time to chew it.

How novel is the flavour of the jelly?

Not at all novel

Extremely novel

How sweet is the jelly?

Not at all sweet

Extremely sweet

How bitter is the jelly?

Not at all bitter

Extremely bitter

How pleasant is the jelly?

Not at all pleasant

Extremely pleasant

Now Please turn the page

Finally, Please compare the drink and the jelly

How similar is the flavour of the drink to the flavour of the jelly?

Not at all similar |-----| Extremely similar

How similar is the intensity of the flavour of the drink to the intensity of the flavour of the jelly?

Not at all similar |-----| Extremely similar

Appendix P: VAS for Exposure Sessions in Experiment 6

P No. Session Time (1)

Using these scales:

Place a **vertical line** through the scale in the position that best describes how you feel **right now**, as shown in this example:

EXAMPLE Happiness:

Not at all happy		_____ / _____		Extremely happy
------------------	--	---------------	--	-----------------

Please answer how you feel **right now**:

Alert:

Not at all alert		_____		Extremely alert
------------------	--	-------	--	-----------------

Hungriness:

Not at all hungry		_____		Extremely hungry
-------------------	--	-------	--	------------------

Relaxed:

Not at all relaxed		_____		Extremely relaxed
--------------------	--	-------	--	-------------------

Thirstiness:

Not at all thirsty		_____		Extremely thirsty
--------------------	--	-------	--	-------------------

Tense:

Not at all tense		_____		Extremely tense
------------------	--	-------	--	-----------------

Fullness:

Not at all full		_____		Extremely full
-----------------	--	-------	--	----------------

Lethargic:

Not at all lethargic		_____		Extremely lethargic
-------------------------	--	-------	--	------------------------

Now please turn the page.

P No. Session Time (2)

Please **taste** the drink and mark your assessment of it on the following scales:

Sweetness:
Not at all sweet |-----| Extremely sweet

Sourness:
Not at all sour |-----| Extremely sour

Pleasantness:
Not at all pleasant |-----| Extremely pleasant

Bitterness:
Not at all bitter |-----| Extremely bitter

Novelty:
Not at all novel |-----| Extremely novel

And finally, how strong is your desire to drink more of this drink?

Not at all strong desire |-----| Extremely strong desire

Now please drink **all** of the drink.

When you have finished, please turn the page.

P No.

Session

Time (3):

Please answer how you feel **right now**:

	Alert:	
Not at all alert	<input type="text"/>	Extremely alert
	Hungriness:	
Not at all hungry	<input type="text"/>	Extremely hungry
	Relaxed:	
Not at all relaxed	<input type="text"/>	Extremely relaxed
	Thirstiness:	
Not at all thirsty	<input type="text"/>	Extremely thirsty
	Tense:	
Not at all tense	<input type="text"/>	Extremely tense
	Fullness:	
Not at all full	<input type="text"/>	Extremely full
	Lethargic:	
Not at all lethargic	<input type="text"/>	Extremely lethargic

Now please call the experimenter.

P No. Session Time (4):

Please do not eat or drink anything except water for **1-hour** after you have left the laboratory.

Please complete this sheet once the **1 hour** period is up.

Today, that means completing this sheet at _____

Please answer how you feel **right now**:

Alert:
Not at all alert | _____ | Extremely alert

Hungriness:
Not at all hungry | _____ | Extremely hungry

Relaxed:
Not at all relaxed | _____ | Extremely relaxed

Thirstiness:
Not at all thirsty | _____ | Extremely thirsty

Tense:
Not at all tense | _____ | Extremely tense

Fullness:
Not at all full | _____ | Extremely full

Lethargic:
Not at all lethargic | _____ | Extremely lethargic

Please bring this sheet with you when you next visit the lab.

Appendix Q: Participant Debrief Form for Experiment 6

P Date

Some final questions...

The Purpose of the Experiment

In your own words, please write one or two sentences on what you think this experiment was about:

How similar was the taste of the drink (on pen & paper test days), and the taste of the jelly (on computer test days)?

Not at all similar

Extremely similar

Appendix R: Conferences attended and presentations given

British Feeding and Drinking Group 30th Annual Meeting and 2006 Food Choice Conference

University of Birmingham, UK, 19th - 21st April 2006

Mars UK sensory projects review

Mars UK, Slough, UK, 25th May 2006

Oral presentation (data from Experiment 1): Sensory-specific satiety and exposure effects

Mars UK external project review

Mars UK, Waltham on the Wolds, UK, 4th August 2006

Oral presentation (data from Experiments 1 and 2): Sensory-specific satiety in a snack food context

British Feeding and Drinking Group Annual Meeting 2007

Caledonian Hotel, Newcastle upon Tyne, UK, 2nd - 3rd April 2007

Oral presentation (data from Experiment 1): Exposure effects and Sensory-specific Satiety

Mars UK external project review

Mars UK, Slough, UK, 16th November 2007

Oral presentation (data from Experiments 1, 2, 3, 4 and 5): Project update: Is sensory-specific satiety modulated by learned food preferences and learned satiety?

British Feeding and Drinking Group Annual Meeting 2008

Liverpool John Moores University (LJMU), UK, 26th - 27th March 2008

Oral presentation (data from Experiment 5): Sensory-specific satiety: an expression of learned satiety?